Oceanography

Temperature & Salinity of the Oceans

Vertical & Horizontal Temperature Distribution of Oceans

Oceans play a significant role in regulating the Earth's temperature by absorbing over 80% of the solar radiation that reaches our planet. Water has an exceptional ability to absorb heat, with the top 10% of the oceans containing more heat than the entire atmosphere. However, ocean temperatures are not consistent throughout and can vary due to several factors.

These factors include:

- **Latitude:** Ocean surface temperature decreases as one moves from the equator towards the poles. This is because the Sun's rays are vertical at the equator and become slanted as they reach the poles.
- **Prevailing Winds:** The direction of prevailing winds, such as Trade Winds and Westerlies, can determine the surface temperature of ocean waters. For example, the eastern edges of the ocean along the trade wind belt have cooler waters due to the warm waters being pushed away from the coast, causing upwelling of cold bottom waters.
- **Unequal distribution of Land and Water:** The Northern Hemisphere has more land area than the Southern Hemisphere, resulting in warmer Northern Oceans compared to the Southern Oceans.
- **Evaporation Rate:** The rate of evaporation varies across different latitudes, with warmer tropical ocean waters having higher evaporation rates than cooler temperate ocean waters.
- **Water density:** The density of ocean water is primarily influenced by its temperature and salinity, which also varies across latitudes. High salinity areas have ocean waters with relatively higher temperatures and vice versa.
- **Ocean Currents:** Surface temperatures of oceans are affected by cold and warm currents. Warm water increases temperature and evaporation rates, leading to more rainfall, while cold currents decrease temperature, resulting in more fog but less precipitation.
- **Local Factors:** Various local factors such as submarine ridges, weather conditions (storms, cyclones, winds, fogs, cloudiness), evaporation rates, and precipitation can also impact ocean temperature distribution.

Understanding ocean temperatures is crucial for determining the movement of vast water volumes (ocean currents), the distribution of marine organisms at different ocean depths, and the climate of coastal lands. The primary source of heat in oceans is the Sun, which provides solar energy (insolation). The Earth's interior also provides heat to the ocean, though this contribution is minimal compared to the Sun's input.

Vertical Distribution of Temperature

The distribution of temperature in the ocean varies with depth, as both sunlight and energy decrease as one goes deeper. At the ocean surface, only about 45% of light energy penetrates to a depth of one meter, and just 16% reaches 10 meters deep. Based on temperature differences, the ocean can be divided into three main zones:

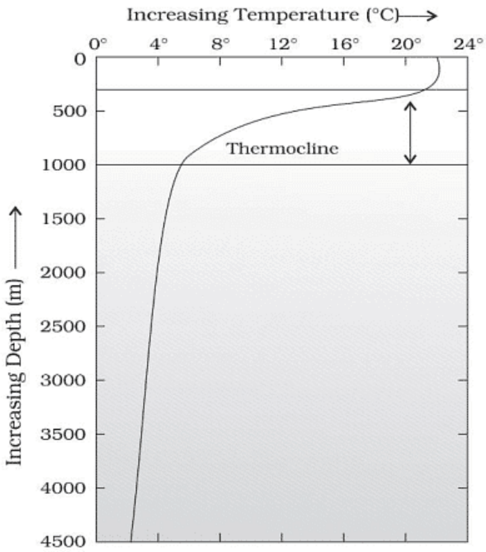
- **Surface Zone or Mixed Zone:** Also known as the Photic or Euphoric zone, this is the top layer of the ocean where temperature and salinity remain relatively consistent. It makes up approximately 2% of the ocean's total water volume and extends to a depth of around 100 meters.
- **Thermocline:** Located between 100 and 1000 meters deep, this zone contains about 18% of the ocean's total water volume. In the thermocline, there is a sharp decline in temperature as the water density increases with depth.
- **Deep Zone:** Found below 1000 meters in mid-latitude regions, this zone comprises roughly 80% of the ocean's total water volume. The temperature in the deep zone remains constant, with the ocean floor having a temperature only one or two degrees Celsius above the freezing point.

What factors influence the distribution of ocean temperature?

A. Latitude and prevailing winds **B.** Evaporation rate and water density **C.** Ocean currents and local factors **D.** All of the above

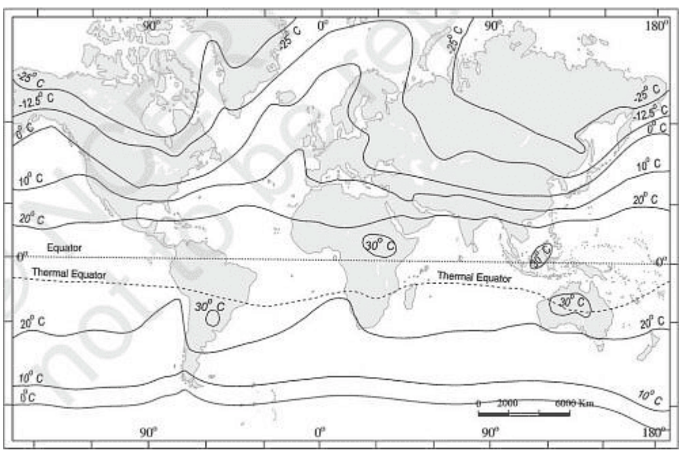
Thermocline

- A thermocline is a transitional layer in the ocean that separates the warmer surface water from the colder deep water.
- This boundary region is typically found at a depth of 100 to 400 meters below the sea surface and extends downward for several hundred meters.
- Within the thermocline, there is a rapid decrease in temperature, and approximately 90% of the ocean's total water volume is located below this layer in the deep ocean.
- In this deep ocean zone, temperatures can reach close to 0°C.



Horizontal Temperature Distribution of Oceans

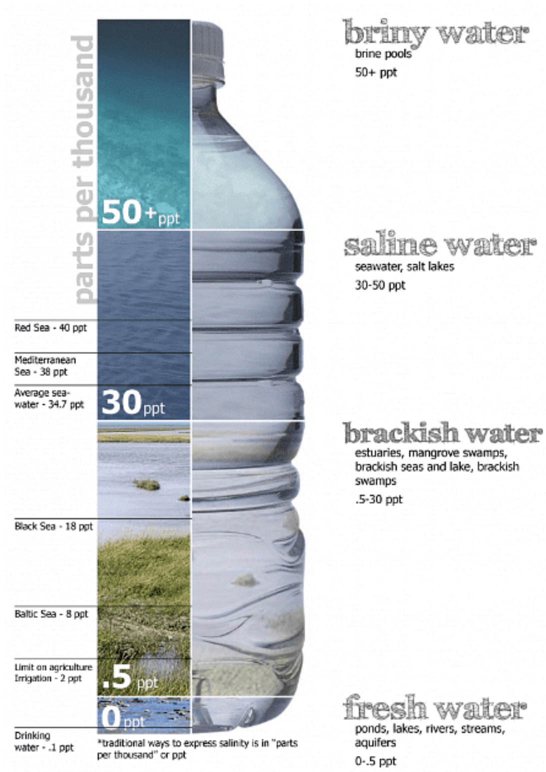
- The temperature distribution of ocean waters varies across different latitudes, with surface water temperatures generally being higher in the lower latitudes and decreasing towards the poles. In the lower latitudes, surface water temperatures are typically around 26 degrees Celsius.
- In the Northern Hemisphere, the average ocean temperature is 19.4 degrees Celsius. However, this average temperature varies depending on the latitude, with 22 degrees Celsius recorded at 20 degrees latitude, and 14 degrees Celsius recorded at 40 degrees latitude. Near the poles, the temperature drops to 0 degrees Celsius.
- Throughout the year, ocean water temperatures in the Northern Hemisphere fluctuate, with the maximum and minimum temperatures usually occurring in August and February, respectively. The average annual temperature range is about 12 degrees Celsius.
- The North Atlantic Ocean experiences the highest annual temperature range, and inland seas generally have a higher temperature range compared to open oceans. Overall, the horizontal distribution of ocean temperatures is influenced by factors such as latitude, seasonal changes, and the location of different bodies of water.



The distribution of surface air temperature in the month of January

Salinity of Ocean Water

- Ocean salinity refers to the total amount of dissolved salts present in seawater. It is measured by calculating the quantity of salt present in 1,000 grams of seawater and is typically expressed in 'parts per thousand' (ppt). A salinity level of 24.7% is considered the maximum threshold for classifying water as 'brackish.'
- Salinity plays a crucial role in determining various chemical characteristics of natural water bodies and influencing biological processes. On maps, isohalines are used to depict the salinity levels of different locations. These lines connect places with equal salinity levels.
- On average, the salinity of the ocean is around 3.5% or 35 parts of salt per 1,000 parts of water.



Water Salinity

The salinity of the Great Salt Lake, (Utah, USA**), the Dead Sea, and the Lake Van in Turkey are 220, 240, and 330 respectively**. The oceans and salt lakes are becoming saltier as time goes on because the rivers dump more salt into them, while freshwater is lost due to evaporation.

Role of Ocean Salinity

- Salinity determines compressibility, thermal expansion, temperature, density, absorption of insolation, evaporation, and humidity.
- It also influences the composition and movement of the sea: water and the distribution of fish and other marine resources.

Share of different salts is as shown below—

Highest salinity in water bodies
Lake Van in Turkey (330°/$_{oo}$),
Dead Sea (238°/$_{oo}$),
Great Salt Lake (220°/$_{oo}$)

Table 13.4 : Dissolved Salts in Sea Water (gm of Salt per kg of Water)

Chlorine	18.97
Sodium	10.47
Sulphate	2.65
Magnesium	1.28
Calcium	0.41
Potassium	0.38
Bicarbonate	0.14
Bromine	0.06
Borate	0.02
Strontium	0.01

Most Saline Water Bodies

- sodium chloride — 77.7%
- magnesium chloride—10.9%
- magnesium sulphate —.4.7%
- calcium sulphate — 3.6%
- potassium sulphate — 2.5%

Factors Affecting Salinity of Ocean Water

- There are certain areas in the ocean where minimal rainfall occurs, but strong, warm, and dry winds lead to a high rate of evaporation. When water evaporates, the water vapor rises into the atmosphere, leaving the salt behind. This results in an increase in the salinity of the seawater, making it denser. The North and South Atlantic Oceans, for example, have high salinity levels due to the presence of powerful winds and limited rainfall.
- The Mediterranean Sea in Europe is another area with significantly high salinity levels, often exceeding 38 parts per thousand (ppt). This is mainly because the Mediterranean Sea is relatively isolated from the main ocean, and the rate of evaporation surpasses the amount of rainfall and freshwater input from rivers.

Rate of Evaporation

- Compare to the temperate latitude ocean, the **ocean between 20°N and 30°N latitudes has higher salinity because of a higher rate of evaporation (because of high temperature)**.

- But this doesn't mean that tropical oceans will have higher salinity because of the points mentioned in the next point.

The amount of freshwater added by precipitation, streams, and icebergs

- The salinity of a body of water is influenced by the amount of freshwater added through various sources, such as precipitation, streams, and icebergs. In regions with high daily rainfall, high relative humidity, and an influx of freshwater, the salinity tends to be lower.
- For example, ocean waters where large rivers like the Amazon, Congo, Ganges, Irrawaddy, and Mekong flow into have lower salinity levels due to the significant amount of freshwater they contribute. Additionally, the Baltic, Arctic, and Antarctic waters have salinity levels below 32 parts per thousand (ppt) because they receive a substantial amount of freshwater from melting icebergs and several large rivers that flow towards the poles.

The degree of water mixing by currents

- **Regions that are land-locked (enclosed by lands) have higher salinity because of no mixing of freshwater + continuous evaporation. E.g. – Black Sea, Caspian Sea, red sea, Persian Gulf**
- The range of salinity is negligible where there is free mixing of water by surface and subsurface currents.

Sea	Salinity (in ppt)
Baltic Sea	7
Red sea	39
Caspian Sea	180
Dead Sea	250
Lake Van	330

Horizontal Distribution of Salinity

To make life easier, I will remove the symbol o/oo and place only the number.

- The salinity for normal open ocean ranges between 33 and 37.

High Salinity Regions

- In the **landlocked Red Sea** (don't confuse this to the Dead Sea which has much greater salinity), **it is as high as 41**.
- In hot and dry regions, where evaporation is high, the salinity sometimes reaches 70.

Comparatively Low Salinity Regions

- In the **estuaries** (enclosed mouth of a river where fresh and saline water get mixed) and the Arctic, the salinity fluctuates **from 0 – 35, seasonally** (freshwater coming from ice caps).

Pacific

- The salinity variation in the Pacific Ocean is mainly due to its shape and larger areal extent.

Atlantic

- The Atlantic Ocean has an average salinity level ranging from 36 to 37.
- In the equatorial region, the salinity is approximately 35, due to the heavy rainfall, high humidity, cloudiness, and the calm air of the doldrums near the equator.
- On the other hand, the polar regions have lower salinity levels, between 20 and 32, as they experience minimal evaporation and receive a large amount of freshwater from melting ice.
- The highest salinity level, 37, can be found between 20° N and 30° N latitude and 20° W and 60° W longitude, with a gradual decrease as one moves northward.

Indian Ocean

- The Indian Ocean has an average salinity level of 35. In the Bay of Bengal, a lower salinity level can be observed, primarily because of the freshwater influx from the Ganges River.
- In contrast, the Arabian Sea experiences higher salinity levels as a result of increased evaporation and a limited supply of fresh water.

Marginal seas

- The North Sea, despite being situated in higher latitudes, exhibits increased salinity as a result of the more saline water transported by the North Atlantic Drift. In contrast, the Baltic Sea has lower salinity levels due to the significant influx of freshwater from rivers.
- The Mediterranean Sea experiences higher salinity levels as a result of substantial evaporation. However,

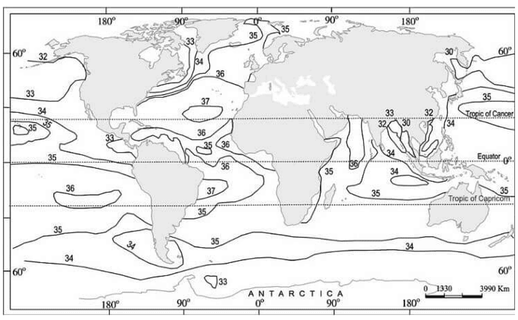
the Black Sea has exceptionally low salinity levels due to the immense inflow of freshwater from surrounding rivers.

Inland Seas and Lakes

- Inland seas and lakes have a high salinity level due to the constant influx of salt from rivers that flow into them. As water evaporates from these bodies of water, the salt concentration increases, making them progressively more saline over time.
- For example, the Great Salt Lake in Utah, USA, the Dead Sea, and Lake Van in Turkey have salinity levels of 220, 240, and 330, respectively.
- The salinity of oceans and salt lakes continues to rise as rivers deposit more salt into them and freshwater evaporates.

Cold and Warm Qater Mixing Zones

- Salinity decreases from 35 – 31 in the western parts of the northern hemisphere because of the influx of melted water from the Arctic region.



- Surface Salinity of World Oceans

Sub-Surface Salinity

- **With depth, the salinity also varies, but this variation again is subject to latitudinal difference. The decrease is also influenced by cold and warm currents**.
- In high latitudes, salinity increases with depth. In the middle latitudes, it increases up to 35 metres and then it decreases. At the equator, **surface salinity is lower**.

Vertical Distribution of Salinity

- The distribution of salinity in the ocean varies with depth, and this variation is influenced by the sea's location. Surface salinity can increase due to water loss from ice formation or evaporation, or it can decrease when freshwater, such as river water, enters the sea.
- However, salinity at deeper levels remains relatively constant, as there is no mechanism for water loss or salt addition at these depths.
- Consequently, a noticeable difference in salinity exists between the surface and deep ocean zones.
- Lower salinity water typically floats above denser, higher salinity water. In general, salinity increases as depth increases, and there is a specific zone known as the halocline where the salinity changes sharply. When other factors are held constant, an increase in seawater salinity causes the water's density to rise. As a result, high salinity water tends to sink below lower salinity water, leading to stratification based on salinity levels.

Salt Budget

The salt budget, also known as the salt cycle, is a process that encompasses the movement of salt from the ocean to the lithosphere, and to a lesser extent, the atmosphere, before eventually returning to the ocean. This cycle operates over an extended period of time.

- As water moves across the Earth's surface, it erodes minerals from rocks and carries them into rivers and streams. This mineral-rich water then flows into the ocean, contributing to its salinity levels. Over time, some of these salts accumulate on the ocean floor through sedimentation, eventually turning into mineralized rocks.
- Over millions of years, geological processes such as plate tectonics and volcanic activity cause some of these rocks to rise above the ocean surface, returning the salt to the lithosphere in the form of minerals. Additionally, wind can carry small amounts of salt from the ocean into the atmosphere, where it can later return to land through precipitation. However, this atmospheric transfer represents a relatively minor portion of the overall salt movement between land and sea.
- In summary, the salt budget is a long-term process that involves the movement of salt from the ocean to the lithosphere and atmosphere, and ultimately back to the ocean. This cycle is primarily driven by the erosion of minerals from rocks and the geological processes that lift these minerals back to the Earth's surface.

Which zone in the ocean experiences a rapid decrease in temperature with depth? A. Surface Zone or Mixed Zone **B.** Thermocline **C.** Deep Zone **D.** Halocline

Conclusion

The temperature and salinity distribution of oceans play a vital role in regulating the Earth's climate, supporting marine life, and influencing coastal environments. Both temperature and salinity vary vertically and horizontally across the ocean, with factors such as latitude, prevailing winds, ocean currents, and local conditions impacting their distribution. Understanding these variations is crucial for predicting climate changes, managing marine resources, and studying the Earth's geological processes. The salt budget, a long-term process involving the movement of salt between the ocean, lithosphere, and atmosphere, further highlights the interconnected nature of the Earth's various systems.

What factors influence the distribution of ocean temperatures?

The distribution of ocean temperatures can be influenced by factors such as latitude, prevailing winds, the unequal distribution of land and water, evaporation rates, water density, ocean currents, and local factors such as submarine ridges, weather conditions, and precipitation.

What are the three main zones of the ocean based on temperature differences?

The three main zones of the ocean based on temperature differences are the Surface Zone or Mixed Zone, the Thermocline, and the Deep Zone.

What is a thermocline, and why is it significant in understanding the distribution of ocean temperatures?

A thermocline is a transitional layer in the ocean that separates the warmer surface water from the colder deep water. It is significant in understanding the distribution of ocean temperatures because it marks a rapid decrease in temperature as the water density increases with depth, and approximately 90% of the ocean's total water volume is located below this layer in the deep ocean.

How does salinity affect the distribution and movement of marine organisms and water in the ocean?

Salinity influences the density, temperature, and chemical properties of ocean water, which in turn affects the movement of water masses and ocean currents. It can also impact the distribution and behavior of marine organisms, as different species have varying tolerance levels for salinity.

What factors contribute to the variation in salinity levels in the oceans?

Factors that contribute to the variation in salinity levels in the oceans include the rate of evaporation, the amount of freshwater added by precipitation, streams, and icebergs, the degree of water mixing by currents, and the location and shape of the ocean.

1. What is the vertical distribution of temperature in the oceans?

Ans. The vertical distribution of temperature in the oceans refers to how the temperature changes with depth. Generally, the temperature decreases as you go deeper into the ocean. This is because sunlight can only penetrate the top layer of the ocean, called the surface mixed layer, and as you go deeper, there is less sunlight to warm the water.

2. How does salinity affect the temperature of ocean water?

Ans. Salinity affects the temperature of ocean water by influencing its density. As salinity increases, the density of the water also increases. This affects the circulation of the ocean, as denser water tends to sink and less dense water rises. These movements, known as ocean currents, can transport heat from one region to another, affecting the temperature distribution.

3. What factors affect the salinity of ocean water?

Ans. Several factors can affect the salinity of ocean water. The main factors include evaporation, precipitation, river runoff, and ice formation and melting. Evaporation increases the salinity of the water, as water molecules evaporate, leaving behind the dissolved salts. Precipitation, on the other hand, decreases the salinity as it adds freshwater to the ocean. River runoff can introduce freshwater and dilute the salinity, while ice formation and melting can also affect the salinity balance.

4. How does the vertical distribution of temperature impact marine life?

Ans. The vertical distribution of temperature in the oceans plays a crucial role in determining the distribution and abundance of marine life. Different species have specific temperature requirements, and variations in temperature can affect their growth, reproduction, and survival. The vertical temperature distribution also influences the availability of nutrients and the mixing of water, which are essential for supporting marine ecosystems.

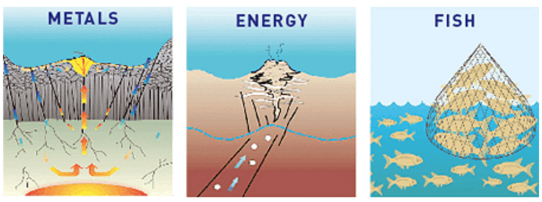
5. How is the vertical distribution of temperature measured in the oceans?

Ans. The vertical distribution of temperature in the oceans is typically measured using instruments called CTD (Conductivity, Temperature, and Depth) profilers. These instruments are equipped with sensors that measure temperature and conductivity (which is related to salinity) at various depths. The CTD profiler is lowered into the water and records temperature readings as it descends, providing scientists with valuable data on the vertical temperature distribution.

Ocean Resources & Ocean Deposits, Biotic, Mineral & Energy Resources

Ocean Resources

- The ocean is a crucial natural resource on Earth, with immense value in various aspects. It is a primary source of food, yielding around 200 billion pounds of fish and shellfish each year. This vast resource supports employment, trade, and essential services for billions of individuals worldwide.
- In addition to food, the ocean supplies numerous other resources. These include fuel, renewable energy, and minerals such as salt, sand, gravel, manganese, copper, nickel, iron, and cobalt, which can be found in the deep sea. Crude oil is also extracted through offshore drilling. Furthermore, the ocean supports the tourism industry, contributing significantly to the global economy.

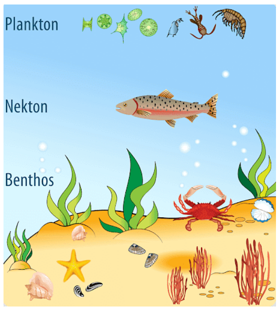


Ocean Resources

The ocean plays a critical role in removing carbon from the atmosphere and providing oxygen. It regulates Earth's climate. Typically **Ocean Resources can be classified in to two** broad categories –

- **Biotic Resources**
  - Planktons
  - Nektons
  - Benthos
- **Abiotic Resources**
  - Mineral
  - Energy

Biotic Resources

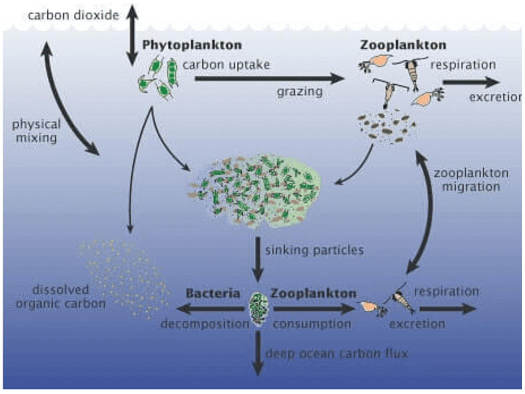
- **Biotic means alive** and **Abiotic means nonliving**.
- Biotic resources of the seas include **fishes, crustaceans, molluscs, corals, reptiles and mammals etc**.
- 

- Marine Biotic Resources

Planktons

Plankton are the diverse collection of organisms found in water that are unable to propel themselves against a current.

- **Phytoplanktons–** floating and drifting micro plants.
- Autotrophs
- Eg- **algae and diatoms**
- **Zooplanktons–** floating and drifting micro animals.

- 
- Plankton
- 

- Phytoplanktons

Nektons

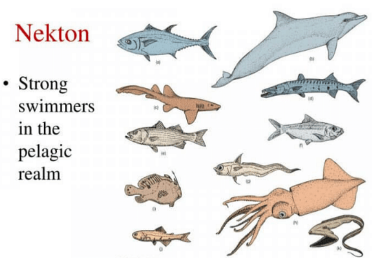
Nekton (or swimmers) are living organisms that are able to swim and move independently of currents at various depths of seas and oceans.

Nektons –

- **fishes**
  - pelagic
  - demersal
- **mammals**
  - dolphin
  - Blue
  - whale

Fishes

- Pelagic fish live in the pelagic zone of ocean or lake waters – being neither close to the bottom nor near the shore
- Demersal fish that live on or near the bottom.

- 

- Nekton

Benthos

Benthos refers to the collection of organisms that inhabit the bottom regions of various bodies of water, specifically the benthic zone. These creatures can be found in various environments, ranging from shallow tidal pools along the shoreline to the deeper regions of the continental shelf, and even reaching the depths of the abyssal zone. In essence, the benthos community consists of organisms that dwell on, within, or near the ocean floor or the bottom of other water bodies.

- mobile
- immobile

- Benthos

Which of the following is NOT a component of the Blue Economy? A. Sustainable marine energy **B.** Sustainable fishing practices **C.** Deforestation for industrial development **D.** Waste management strategies

Mineral Reserves

- Mineral dissolved in seawater
- Continental Shelf and Slope Deposits
- Deep ocean bottom deposits

1. Mineral dissolved in sea-water

- Salt
- Bromine
- Magnesium
- Gold
- Zinc
- Uranium
- Thorium

2. Continental Shelf and Slope Deposits

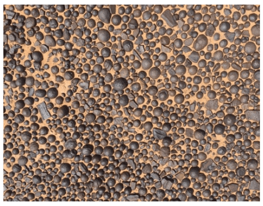
- Sulfur – associated with marine volcanism.
  - Ex. Gulf of Mexico – a rich source of sulfur

Magnetite reserves are found along the **circum pacific volcanic belt**.

- monazite sand (source of thorium) at Kerala coast
- Gold (Alaska)
- Zircon (Brazil, Australia)
- Diamond (SouthAfrica)
- Calcium-– Peruvian coast rich deposits of calcium and phosphate
- Sand and gravel – significant building materials widely found on beds of continental shelves
- Fishes are rich in nitrate and phosphate, high protein, medicinal use
- Pearls

3. Deep ocean bottom deposits

- **Manganese nodules–** It comprises several minerals like nickel, copper, cobalt, lead, zinc, etc.
- The maximum percentage of Iron and Manganese.
- **Cobalt-rich marine deposits associated** with seamounts and guyots.
- **Phosphate-in form of phosphoritic modules** on shallow seabeds.
- **Polymetallic nodules**
    - **Polymetallic nodules are rounded accretions of manganese and iron hydroxides** that cover vast areas of the **seafloor** but are **most abundant on abyssal plains**.

    - 
    - nodule polymétallique

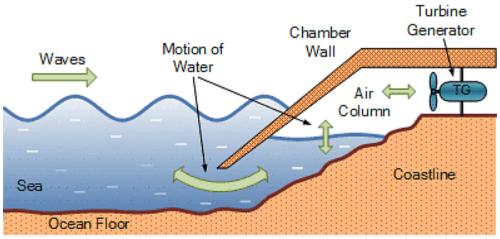
Energy Reserves

- **Renewable**
    - OTEC
    - Wave
    - Tidal
    - Wind
- **Non-Renewable**
    - Gas hydrates
    - Mineral oil
    - Natural gas

Ocean thermal energy conversion (OTEC) –

- Ocean Thermal Energy Conversion (OTEC) is a process that generates electricity by utilizing the temperature differences between deep, cold seawater and warmer, shallow or surface seawater. This temperature difference is used to operate a heat engine, which in turn produces useful work, primarily in the form of electrical power.
- However, due to the relatively small temperature differences involved, the overall thermal efficiency of OTEC systems is quite low. This presents a challenge in terms of the economic viability of large-scale implementation of this technology.

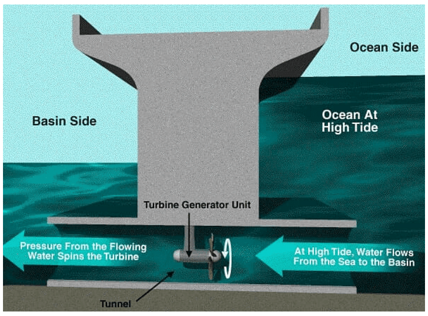
Wave Energy

- Wave energy is produced when electricity generators are placed on the surface of the ocean.
- The energy provided is most often used in desalination plants, power plants, and water pumps. Energy output is determined by wave height, wave speed, wavelength, and water density.
- 

- Wave Energy

Tidal Energy

- Tidal energy is produced through the use of tidal energy generators.
- Large underwater turbines are placed in areas with high tidal movements and are designed to capture the kinetic motion of ocean tides in order to produce electricity.

- 

- Tidal Energy

Offshore Wind Energy

- Offshore wind power or offshore wind energy refers to the construction of wind farms in bodies of water to generate electricity from wind. Stronger wind speeds are available offshore compared to on land, so offshore wind power's contribution in terms of electricity supplied is higher.

- 
- Wind Power

Blue Economy

The Blue Economy concept, introduced by Gunter Pauli in his 2010 book "The Blue Economy: 10 years, 100 innovations, 100 million jobs," refers to the sustainable utilization of ocean resources to promote economic growth, improve livelihoods and job opportunities, and maintain the health of ocean ecosystems. This approach encourages the implementation of environmentally friendly development strategies for increased productivity and preservation of the ocean's well-being.

The Blue Economy encompasses several key areas, including:

- **Renewable Energy:** Sustainable marine energy has the potential to significantly contribute to social and economic progress.
- **Fisheries:** By adopting sustainable fishing practices, the industry can generate higher revenues, increase fish populations, and contribute to the restoration of fish stocks.
- **Maritime Transport:** Sea transportation accounts for more than 80% of international trade, making it a crucial component of the global economy.
- **Tourism:** Ocean and coastal tourism can create employment opportunities and stimulate economic growth.
- **Climate Change:** Oceans act as essential carbon sinks (blue carbon) and play a crucial role in mitigating the effects of climate change.
- **Waste Management:** Implementing better waste management strategies on land can support ocean recovery efforts.

The Blue Economy emphasizes the need to integrate the development of the ocean economy with social inclusion, environmental sustainability, and innovative business models. This approach is reflected in the United Nations' Sustainable Development Goal (SDG 14), which aims to conserve and sustainably use the oceans, seas, and marine resources for sustainable development.

Need for Blue Economy

- Oceans play a vital role in sustaining life on Earth, as they cover 75% of the planet's surface, hold 97% of its water, and make up 99% of its habitable area. They are essential for maintaining biodiversity, regulating the climate, and absorbing approximately 30% of global CO2 emissions. Oceans also contribute significantly to the global economy, with at least 3-5% of the world's GDP generated from ocean-related activities.
- The blue economy, which focuses on the sustainable use of ocean resources, offers immense potential for enhancing economic growth by creating new opportunities for income generation and employment. This can be achieved by supporting food security and diversifying the exploitation of resources, such as renewable energy, valuable chemicals, protein-rich food, deep-sea minerals, and other aspects related to security.
- In summary, the blue economy is an emerging sector that holds great promise for the future, as it harnesses the power of the oceans to promote sustainable development and economic growth.

Challenges

- **The risk of maritime terrorism and criminal activities:** Piracy, armed robbery, and maritime terrorism, along with illegal trade in crude oil, weapons, drugs, and human trafficking, as well as the smuggling of contraband, pose significant threats to the safety and security of the maritime domain.

- **Natural disasters:** Every year, numerous tsunamis, cyclones, hurricanes, and typhoons wreak havoc on coastal communities, leaving thousands of people displaced and causing extensive damage to property and infrastructure.
- **Man-made issues:** Oil spills and climate change have ongoing repercussions on the stability of the marine environment, posing hazards to both ecosystems and the human populations that rely on them.
- **Effects of climate change:** As sea temperatures and acidity levels fluctuate, marine life, habitats, and the communities that depend on them face increasing threats to their survival and well-being.
- **Marine pollution:** The release of excess nutrients from sources such as untreated sewage, agricultural runoff, and marine debris like plastics contributes to the deterioration of the marine environment.
- **Overexploitation of marine resources:** The illegal, unreported, and unregulated extraction of marine resources is a pressing issue that leads to the depletion of valuable species and ecosystems.

Blue Economy for India

- The blue economy offers an unparalleled opportunity for India to achieve its national socio-economic goals and enhance connectivity with neighboring countries. By focusing on generating livelihoods, ensuring energy security, building ecological resilience, and improving the health and living standards of coastal communities, the blue economy can play a crucial role in India's development.
- The implementation of the blue economy will support the Indian government's efforts to achieve the Sustainable Development Goals (SDGs) of eradicating hunger and poverty, as well as promoting the sustainable use of marine resources by 2030. With a coastline spanning 7,517 km across nine states and two union territories, India's Exclusive Economic Zone (EEZ) covers an area of 2.02 million square kilometers.
- The marine services sector has the potential to form the backbone of India's blue economy, contributing significantly to the country's goal of becoming a 5 trillion dollar economy by 2025. The Indian Ocean, which serves as a major trade route with approximately 80% of global oil trade passing through it, is a key area for India to focus on.
- Enhancing regional connectivity will not only reduce transportation costs and maritime wastage of resources, but also promote sustainable and cost-effective trade. In summary, the blue economy presents a unique opportunity for India to achieve its socio-economic objectives while fostering stronger regional connections and promoting sustainable development.

Developments Initiated by India

India has initiated several developments to enhance its maritime sector, such as the Sagarmala Project, which is a strategic initiative aimed at port-led development through the extensive use of IT-enabled services for modernizing ports. This project aims to revolutionize maritime logistics by developing inland waterways and coastal shipping, which will create millions of new jobs, reduce logistics costs, and more.

- One of the main focuses of the Sagarmala Project is the sustainable development of coastal communities and the people living in them. This includes promoting the responsible use of ocean resources, introducing modern fishing techniques, and developing coastal tourism.
- Under the umbrella of the Ocean Services, Modelling, Application, Resources, and Technology (O-SMART) scheme, India aims to regulate the use of oceans and marine resources for sustainable development. Additionally, the Integrated Coastal Zone Management (ICZM) project focuses on conserving coastal and marine resources and improving livelihood opportunities for coastal communities.
- The development of Coastal Economic Zones (CEZ) under the Sagarmala Project is expected to become a key component of the blue economy, wherein industries and townships that rely on the sea will contribute to global trade.
- Furthermore, India has implemented a National Fisheries Policy to promote the 'Blue Growth Initiative,' which emphasizes the sustainable utilization of fisheries wealth from marine and other aquatic resources. Overall, these initiatives reflect India's commitment to developing its maritime sector in a sustainable and responsible manner, benefiting both the environment and the people who depend on it.

What is the primary goal of India's Sagarmala Project?

A. Expanding agricultural lands **B.** Port-led development through modernization of ports **C.** Increasing the production of fossil fuels **D.** Building more coastal resorts

Conclusion

The ocean is a vital resource that offers significant economic, ecological, and societal benefits. The blue economy concept emphasizes the sustainable use of ocean resources to

promote economic growth, improve livelihoods, and maintain the health of marine ecosystems. India, with its extensive coastline and strategic location in the Indian Ocean, has the potential to harness the blue economy for socio-economic development, environmental sustainability, and regional connectivity. Through initiatives such as the Sagarmala Project, O-SMART scheme, and the National Fisheries Policy, India is working towards realizing the full potential of its maritime sector while ensuring the well-being of coastal communities and the preservation of marine resources.

What is the blue economy?

The blue economy refers to the sustainable utilization of ocean resources to promote economic growth, improve livelihoods and job opportunities, and maintain the health of ocean ecosystems. It encompasses renewable energy, fisheries, maritime transport, tourism, climate change mitigation, and waste management.

How does the blue economy contribute to sustainable development?

The blue economy emphasizes the need to integrate the development of the ocean economy with social inclusion, environmental sustainability, and innovative business models. This approach supports the United Nations' Sustainable Development Goal (SDG 14), which aims to conserve and sustainably use the oceans, seas, and marine resources for sustainable development.

What are some renewable energy sources derived from the ocean?

Ocean-based renewable energy sources include ocean thermal energy conversion (OTEC), wave energy, tidal energy, and offshore wind energy. These technologies harness the power of temperature differences, waves, tides, and wind to generate electricity.

What are the challenges faced by the blue economy?

Challenges faced by the blue economy include maritime terrorism and criminal activities, natural disasters, man-made environmental issues, climate change impacts on marine life and habitats, marine pollution, and overexploitation of marine resources.

How is India working towards developing its blue economy?

India is focusing on key initiatives such as the Sagarmala Project for port-led development, Ocean Services, Modelling, Application, Resources, and Technology (O-SMART) scheme for regulating the use of oceans and marine resources, Integrated Coastal Zone Management (ICZM) project for coastal and marine resource conservation, and the development of Coastal Economic Zones (CEZ) to contribute to global trade.

1. What are ocean resources?

Ans. Ocean resources refer to the various assets and commodities found in the ocean that can be utilized by humans. These resources can include fish and other marine organisms, minerals, energy sources, and even tourism opportunities.

2. What are biotic resources?

Ans. Biotic resources are the living components of the ecosystem, including plants, animals, and microorganisms. In the context of ocean resources, biotic resources can include fish, shellfish, algae, and other marine organisms that are harvested for food, medicine, or other purposes.

3. What are mineral reserves in the ocean?

Ans. Mineral reserves in the ocean are deposits of valuable minerals found on the ocean floor. These minerals can include manganese nodules, cobalt-rich crusts, hydrothermal vents, and phosphorite deposits. They have the potential to be a valuable source of rare earth elements, metals, and other minerals.

4. What are energy reserves in the ocean?

Ans. Energy reserves in the ocean refer to the various energy sources that can be harnessed from the ocean. This can include offshore wind energy, wave energy, tidal energy, and even the potential for harnessing thermal energy from the temperature differences in ocean water.

5. What developments have been initiated by India in ocean resource utilization?

Ans. India has initiated several developments in ocean resource utilization. The country has established the National Institute of Ocean Technology (NIOT) to undertake research and development activities in the areas of ocean resources, such as deep-sea mining, ocean energy, and marine biotechnology. India is also actively engaged in international collaborations and has signed agreements with other countries to explore and develop ocean resources.

Bottom Topography of the Atlantic, Indian & Pacific Oceans

Bottom Reliefs of the Atlantic Ocean:

- The Atlantic Ocean located between North and South Americas in the west and Europe and Africa in the east covers an area of 82,000,000 km2 which is 1/6th of the geographical area of the globe and half of the area of the Pacific Ocean.
- The 'S' shape of the ocean indicates the fact that landmasses (continents) on its either side were once a contiguous part.
- The Atlantic Ocean was formed due to drifting of North and South Americas to the west due to plate tectonics.
- The ocean widens to the south of equator and attains the maximum width of 5,920 km at 35°S latitude. It narrows down towards the equator.
- It is only 2560 km wide between Liberian coast and Cape Sao Roque. The width further increases northward and it becomes 4800 km at 40°N latitude.
- It narrows down in the extreme north where it maintains its contact with the Arctic Ocean through Norwegian Sea, Denmark Strait and Davis Bay.
- The average depth of the ocean is less than the Pacific Ocean because of extensive continental shelves and marginal and enclosed seas. About 24 per cent of the Atlantic Ocean is less than 915m deep.

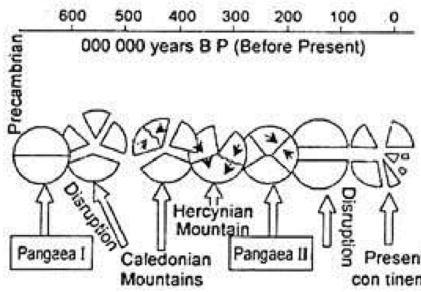


Fig. 5.13 : The probable pattern of continental movement during the last 700 million years (based on Valentine and Moors. 1970)

Continental Shelf:

- Continental shelves have developed along both the coasts of the Atlantic Ocean and the width ranges from 2-4 km to more than 80 km.
- In fact, the width of continental shelves has been largely controlled by the reliefs of the coastal lands.
- These become significantly narrow where mountains and hills border the coasts e.g., the African shelves between Bay of Biscay and Cape of Good Hope and Brazilian shelves between 5°S and 10°S latitudes.
- The shelves become 200 to 400 km wide along the north-eastern coast of North America and the north-western coast of Europe. Extensive shelves are found around Newfoundland (Grand Bank) and British Islands (Doggar Bank).
- Similarly, the continental shelves around Greenland and Iceland are quite wide.

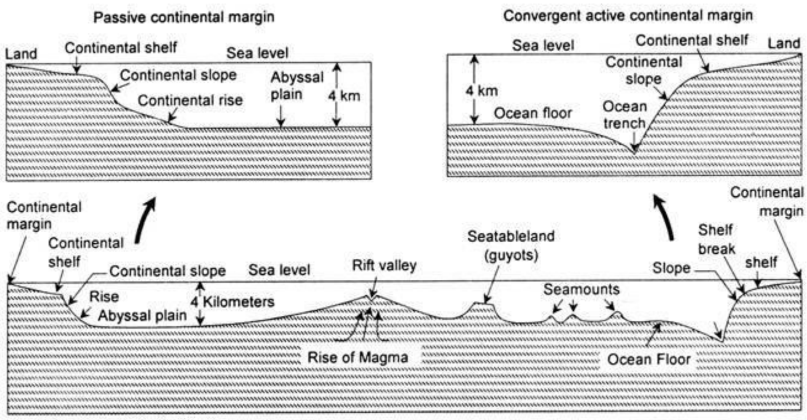


Fig. 24.2 : Configuration of ocean floors; modified from Thurman and Treijillo, 1999.

Mid-Atlantic Ridge:

- The mid-Atlantic ridge representing the zone of divergent or constructive plate margins (American plates moving westward and Eurassian and African plates moving to the east) is the most striking relief feature which having S shape extends for 14,450 km from Iceland in the north and to Bouvet Island in the south.
- Though swinging west and east it maintains its central position and nowhere goes down more than 4000m below sea level.
- The ridge is known as Dolphin Rise to the north and Challenger Rise to the south of equator. It is known as Wyville Thompson Ridge between Iceland and Scotland.
- The ridge becomes quite extensive to the south of Greenland and Iceland and is called Telegraphic Plateau because first cabbies were laid down in this area.

Ocean Basins:

The mid-Atlantic Ridge divides the Atlantic Ocean into two major basins viz. East and West Atlantic Basins.

- Labrador basin extends between the continental shelf of Greenland in the north and Newfoundland Rise in the south covering latitudinal extent of 40° N to 50°N where the depth of the basin ranges from 4,000 to 4,500m.
- North American basin is the most extensive basin of the Atlantic Ocean and extends between 12°N and 40° latitudes. The east-west section lies between the continental shelves off the east coast of N. America and 50°W meridian. The depth of the basin is more than 5000m but a few deeps measure more than 6000m depth.
- Brazilian basin is confined between the equator and 30°S latitude and east coast of Brazil in the west and Para Rise in the east. The depth is more than 4,000m.
- Spanish basin is located between the mid- Atlantic Ridge and Iberian Peninsula. It is bordered by Azores Rise in the south and extends upto 50°N latitude. The average depth is 5,000m.
- North and South Canary basin is comprised of two almost circular basins and is 5,000m deep.
- Cape Verde basin is located between the mid- Altlantic Ridge and west African coast and extends from 10° N to 23.° N. Average depth is 5000 m but at few places it becomes 5000 m or more.
- Guinea basin extends from north-east to southwest in elongated shape between Guinea Ridge and Sierra Leone Rise and measures 4,000 to 5,000 m in depth.
- Angola basin is located between the equator and 30°S latitude. It stretches from the African coast in the north-east to the knot of the mid-Atlantic Ridge and Walvis Ridge in the south-west. The basin is most extensive near the African coast and narrows down towards south-west. The average depth is 5,000m.

Ocean Deeps:

- The number of deeps in the Atlantic Ocean is far less than in the Pacific Ocean because of the absence of the effects of Tertiary orogenic movements along the Atlantic coasts. Murray has identified 29 deeps upto the depth of 3,000 fathoms (5,486.4m) in the Atlantic Ocean.
- Nares Deep (6,000m), Pureto Rico Deep (8,385m), Hatteras Deep (5,445m), Columbia Deep (5,125m, south of Haiti), Valdivia Deep (3,134 fathoms), Tizard or Romanche Deep (9,370m), Buchanan Deep (3,063 fathoms), Moseley Deep (3,309 fathoms), Vema Deep (4,900m) etc. are a few important ocean deeps of the Atlantic Ocean.
- The Mediterranean Sea, Caribbean Sea and Gulf of Mexico are significant marginal seas in the Atlantic Ocean. The Mediterranean Sea is divided into two major basins (East and West Basins) by 4,000m deep mid-sea ridge which runs from the southern Italian coast to the north African coast.
- The Gulf of Mexico and Caribbean Sea are separated by a 1,600 m deep ridge running between Yucatan Peninsula and Cuba Island. The prominent basins are Mexico basin and Caribbean basin. The latter is further divided into four sub-basins e.g. Yucatan basin, Cayman trough, Columbia basin and Venezuela basin.

Bottom Reliefs of the Pacific Ocean:

- The Pacific Ocean, the largest ocean of the world having one-third area of the globe, extends from east to west for 16,000 km from the east coast of Asia in the west to the west coasts of Americas in the east and for 14,880 km from north to south between Bering Strait in the north to Cape Adre (Antarctica) in the south.

Johnson has divided the Pacific Ocean into four sub-regions:

- The Northern Pacific represents the deepest part of the whole Pacific where average depth ranges between 5000m and 6000m. This region makes contact with the Arctic Sea through Bering Strait.

- The Central Pacific is characterized by largest number of islands most of which are of volcanic and coral origin. H.H. Hess has identified 160 flat-topped sea mounts in this region. There are a few sub-parallel island chains which have been named by E. Suess as Oceanides.
- The South-West Pacific carries a large number of islands, marginal seas, extensive continental shelves and oceanic trenches.
- The South-East Pacific has the most striking relief of the Pacific Ocean as the East Pacific Rise or Ridge but there is absence of marginal seas.

Continental Shelf:

- There is significant difference in the extent and characteristics of continental shelves on the eastern and western coasts of the Pacific. The shelves are quite broad and extensive along the eastern coasts of Australia and Asia where the width varies from 160 km to 1600 km and the depth ranges between 1000 m and 2000m.
- These continental shelves also carry numerous marginal seas like Bering Sea, Okhotsk Sea, Japan Sea, Yellow Sea, China Sea, Java Sea, Coral Sea, Tasmania Sea, Arafura Sea etc. The continental shelve are less extensive along the western coasts of Americas because of nearness of cordillerean chains of folded mountains to the coastal lands.

East Pacific Rise:

- The Pacific Ocean does not have central or mid- oceanic ridge like the Atlantic and the Indian Oceans, albeit there are a few scattered ridges having local importance.
- The East Pacific Rise or Ridge known as Albatross Plateau is 1600 km wide and it extends from north of New Zealand to the Californian coast. It sends off two branches between 23°S-35°S.

A minor ridge known as Galapagos Ridge runs parallel to the East Pacific Ridge in the east between the Eastern Island Fracture Zone and Galapagos islands from where in moves in two branches viz.:

- Carnegie Ridge, and
- Cocos Ridge in north-east direction.

Ocean Basins:

- Philippine basin is located to the east of Philippines and extends from south of Japan to 5°N latitude. Kyushu – Paian Ridge runs through the middle of the basins. Average depth ranges from 5000m to 6000m.
- Fiji basin is located to the south of Fiji Island between 10°S and 32°S latitudes and the average depth is 4000m. The basin to the north of 20°S is known as North Fiji Basin whereas the South Fiji Basin between 20°S and 32°S is bordered by Norkolk Island Ridge in the west and Karmadec – Tonga Trenches in the east.
- East Australian basin is situated between the east coast of Australia and New Zealand Ridge with average depth of more than 5000m.
- South Australian Basin also known as Jeffreys Basin is located to the south-east of Australia having average depth of 5000m.
- Peru basin is located to the west of Peru coast between 5°S and 24°S latitudes and extends upto 110°W longitude. The average depth of the basin is 4000m.
- South-Western Pacific basin is an elongated basin stretching between 20°S and 50°S latitudes and 180-129°W longitudes. Karmadec Trench with the depth of 10,047 m is located to the west of this basin.
- Pacific-Antarctic Basin is located to the southwest of Chilean coast between 40°S and 60°S latitudes and extends up to 130°W longitude.

Bottom Reliefs of the Indian Ocean:

- The Indian Ocean is smaller than the Pacific and Atlantic Ocean in areal extent and is bounded by, on all of its sides, Asia in the north, Africa in the west, Asia in the east, Australia in the south-east and Antarctica in the south.
- The ocean has contact with the Pacific and the Atlantic oceans in the south near Antarctica. The average depth of the ocean is 4000m.
- Major parts of the coastal lands of the Indian Ocean formed by the block mountains of Gondwanaland are compact and solid.
- The coasts of the East Indes are bordered by fold mountain chains. The marginal seas are less in number than the Pacific and the Atlantic oceans. Significant marginal seas are Mozambique Channel, Red Sea, Persian Gulf, Andman Sea, Arabian Sea, Bay of Bengal etc. Malgasy (Madagascar) and Sri Lanka are the big islands whereas Suqutra, Zanzibar, Comoro, Reunion, Secychelles, Prince Edwards, Crozet, Kerguelen, St. Paul, Rodriges, Maldive, Laccadive, Andman-Nicobar, Christmas etc. belong to the category of small and tiny

islands. Indian subcontinent in the north divides the Indian Ocean into Arabian Sea and Bay of Bengal.

The ocean widens in the south Johnson has divided the Indian Ocean in 3 zones on the basis of regional characteristics:

- The Western Zone between African coast and the mid-Indian Oceanic Ridge has large number of islands and the average depth is 3650 m (2000 fathoms).
- The Eastern Zone is deepest of all the zones with average depth of 550 m (3000 fathoms). The continental shelves are narrow but have steep slopes.
- The Central Zone represents the mid-oceanic ridge where many tiny islands are located.

Continental Shelf:

- There is wide range of variation in the continental shelves of the Indian Ocean. Quite extensive shelves are found along the margins of Arabian Sea and Bay of Bengal. Similarly, extensive shelves are observed along the eastern coast of Africa and around Madagascar which is itself located on the continental shelves.
- On an average, the continental shelves are very wide (640 km) in the west whereas these are narrow (160 km) along the coast of Java and Sumatra.
- These become further narrow along the northern coast of Antarctica.

Mid-Oceanic Ridge:

- The main central ridge starts from the continental shelf of the southern tip of Indian Peninsisula with average width of 320 km. This part of the ridge is known as Laccadive-Chagos Rigde (also known as Maldive Ridge).
- The ridge further extends southward and widens near equator. It is called Chagos- St. Paul Ridge between equator and 30°S latitude where the average width becomes 320 km.
- The ridge further widens to 1,600 km between 30°S and 50°S latitudes and is known as Amsterdam-St Paul Plateau.
- The central ridge bifurcates to the south of 50°S latitude. The western branch known as Kerguelen-Gaussberg ridge extends in NW-SE direction between 48°S and 63°S and the eastern branch is known as Indian-Antarctic Ridge.

Branches of the Central Ridge:

- Socotra-Chagos Ridge also known as Carlesbreg Ridge emerges from the central ridge at 5°S latitude and extends in northwesterly direction upto Gardafuli Peninsula of N. E. Africa,
- Seychelles – Mauritius ridge bifurcates from the main ridge around 18°S latitude near Mauritius Island and runs in roughly north-west direction in arcuate shape upto Seychelles and Amirante islands.
- Madagascar Ridge stretches from the southern tip of Madagascar (Malagasy) to 40°S latitude. Its further southward extension is known as Prince Edward – Crozet Ridge between 40°S -48°S latitudes.
- Ninety East Ridge extends from the continental shelf off the Irrawadi river mouth and runs in almost north-south direction parallel to 90°E longitude upto 40°S where it merges with Amsterdam- St Paul Plateau.
- The south-western branch near 23°S latitude is known as S.W. Indian Ridge.

Ocean Basins:

- Oman basin faces the Gulf of Oman and is spread over the extensive continental shelf with average depth of 3,658 m.
- Arabian basin is located in almost circular shape between Laccadive-Chagos ridge and Socotra – Chagos Ridge with the depth of 3,600m – 5,486m.
- Somali basin is bordered by Socotra – Chagos ridge in the north-west. Central Ridge in the east, Seychelles – Mauritius Ridge in the south-west and African coast in the west. The average depth is 3,600m.
- Mauritius basin is located between S.W. Indian Ridge and South Madagascar Ridge and extends from 20°S to 40°S latitude. The depth varies between 3,600m and 5,486 m. The deepest part measures 6,391 m depth.
- Mascarene basin of oval shape extends between Madagascar and Seychelles – Mauritius Ridge.
- Agulhas-Natal basin is an elongated basin which is bordered by Madagascar ridge in the north and north-east, Prince Edward Crozet Ridge in the east and the S.E. African coast in the west and north-west, Average depth is 3,600m.
- Atlantic- Indian – Antarctic basin is in fact the eastward continuation of Atlantic – Antarctic Basin. It stretches upto 70°E longitude and is bordered by Prince Edward Crozet Ridge in the north, Antarctica in the south and Kerguelen Gassberg Ridge in the north-east. Average depth is 3,600m.

- Eastern Indian-Antarctic basin is located between Amsterdam – St. Paul Plateau and Indian-Antarctic Ridge in the north and north-east and Antarctica in the south. The depth varies from 3,600m to 4,800m. Kerguelen – Gassberg Ridge separates the basin from the Atlantic – Indian-Antarctic Basin.
- West Australian basin is the most extensive basin and forms rectangular shape surrounded by S.E. Indian Ridge in the south – west, Ninety East Ridge in the west, continental shelves of Java-Sumatra in the northeast and the continental shelf of west Australia, Average depth varies from 3,600m to 6,100m but the central part of the basin is 6,459 m deep.
- Mid-Indian basin is bordered by the central ridge in the west and the south-west, by Ninety East Ridge in the east and by the Bengal plateau in the north. The average depth of outer part ranges from 3,600m to 6,800m while the depth of the central part of the basin ranges between 4,800m and 6,100m.

1. What is the topography of the Atlantic Ocean?

The topography of the Atlantic Ocean is characterized by a variety of features, including underwater mountain ranges, deep trenches, and vast plains. The Mid-Atlantic Ridge, for example, is a prominent mountain range that runs through the center of the Atlantic Ocean. It is formed by the divergent movement of tectonic plates and is marked by volcanic activity. The topography also includes deep trenches, such as the Puerto Rico Trench and the Romanche Trench, which are some of the deepest parts of the ocean. Additionally, there are extensive abyssal plains, which are relatively flat areas covered with sediments.

2. What are the major topographic features of the Indian Ocean?

The Indian Ocean exhibits various topographic features, including underwater mountain ranges, trenches, and plateaus. The Ninety East Ridge, for instance, is a significant submarine volcanic ridge that extends from the Bay of Bengal to the Southern Ocean. It is one of the longest undersea mountain ranges in the world. The Indian Ocean also contains the Java Trench, which is the deepest part of the ocean, reaching depths of over 7,000 meters. Additionally, there are extensive plateaus, such as the Kerguelen Plateau and the Mascarene Plateau, which are characterized by relatively flat areas at greater depths.

3. What is the bottom topography of the Pacific Ocean like?

The bottom topography of the Pacific Ocean is diverse and includes several notable features. The Pacific Ocean is home to the Mariana Trench, which is the deepest part of any ocean, reaching a depth of about 11,000 meters. It is located in the western Pacific and is known for its extreme depth and unique geological formations. The Pacific Ocean also features the Pacific-Antarctic Ridge, another extensive underwater mountain range that extends from the Pacific to the Southern Ocean. Additionally, there are numerous seamounts and abyssal plains throughout the Pacific Ocean, contributing to its rich topographic diversity.

4. How do underwater mountain ranges form in the oceans?

Underwater mountain ranges in the oceans, such as the Mid-Atlantic Ridge and the Ninety East Ridge, form through a process called seafloor spreading. Seafloor spreading occurs along divergent plate boundaries, where tectonic plates move away from each other. As the plates separate, magma rises up from the Earth's mantle to fill the gap. This magma then solidifies and forms new oceanic crust. Over time, this process of magma upwelling and solidification creates a continuous mountain range along the boundary, known as a mid-ocean ridge or underwater mountain range.

5. What role do trenches play in the ocean's topography?

Trenches are crucial features in the ocean's topography as they mark the deepest parts of the ocean. They form at convergent plate boundaries, where tectonic plates collide. In these areas, one plate is forced beneath the other in a process called subduction. The descending plate bends and sinks into the mantle, creating a trench on the ocean floor. Trenches can reach immense depths and are often associated with seismic and volcanic activity. They also play a significant role in the recycling of Earth's crust, as the subducted plate eventually melts back into the mantle, completing the cycle of plate tectonics.

Heat & Salt Budgets

Source of Heat in Oceans

The primary source of heat for the world's oceans is the sun, which provides energy not only for the oceans but for all life on Earth. Additionally, heat from the Earth's interior also contributes to warming the ocean water.

There are three main mechanisms through which ocean water is heated:

- Absorption of solar radiation is highest in low latitude regions due to direct sunlight and longer daylight hours, and gradually decreases towards the poles. Even within the same latitude, the amount of solar energy absorbed by the ocean can vary due to factors such as ocean currents and cloud cover.
- Convection currents within the ocean also contribute to heating the water. As the Earth's temperature increases with depth, the water at the bottom of the ocean heats up more quickly than the water closer to the surface. This causes convection currents to form, transferring heat from the deeper layers to the upper layers of the ocean.
- Friction generated by surface winds and tidal currents produces kinetic energy, which in turn heats the ocean water.

On the other hand, the ocean loses heat through the following processes:

- Back radiation occurs when the solar energy absorbed by the ocean is re-emitted as long-wave radiation from the water's surface.
- Heat exchange between the ocean and the atmosphere takes place when there is a temperature difference between the water and the surrounding air.
- Evaporation cools the ocean water when the surface is cold, the water is warm, and the atmospheric conditions are unstable.

In summary, the sun is the main source of heat for the oceans, while internal heat from the Earth also contributes. Heat is transferred through absorption of solar radiation, convection currents, and friction from winds and currents. The ocean loses heat through back radiation, heat exchange with the atmosphere, and evaporation.

What are the three main mechanisms through which ocean water is heated?

A. Absorption of solar radiation, convection currents, and friction from winds and currents
B. Absorption of solar radiation, convection currents, and evaporation
C. Absorption of solar radiation, friction from winds and currents, and heat exchange with the atmosphere
D. Back radiation, convection currents, and friction from winds and currents

Heat Budget of the Oceans

- **Ocean Heat Budget:** The concept of heat budget suggests that the total energy supply is balanced by an equal amount of energy loss. It has been observed that the average annual surplus of solar radiation between the equator (0°) and 10°N latitude is about 0.170 gm cal/cm2/min, while it is about 0.040 gm cal/cm2/min between 60°N to 70°N. However, this difference in surplus solar radiation disappears when considering all latitudinal regions.
- **Ocean Temperature Range:** Oceans and seas heat up and cool down more slowly than land surfaces. As a result, even if the solar radiation is at its maximum at 12 noon, the ocean surface temperature reaches its highest point at 2 p.m. The average daily temperature range in oceans and seas is only about 1 degree. The highest temperature in surface water occurs at 2 p.m., while the lowest occurs at 5 a.m. The daily temperature range is highest in oceans when the sky is cloud-free and the atmosphere is calm.

The annual temperature range is influenced by the annual variation in solar radiation, the nature of ocean currents, and the prevailing winds. The maximum and minimum temperatures in oceans are slightly delayed compared to land areas, with the maximum occurring in August and the minimum in February. The northern Pacific and northern Atlantic oceans have a greater temperature range than their southern counterparts due to differences in the strength of prevailing winds from land and more extensive ocean currents in the southern parts of oceans.

In addition to annual and daily temperature ranges, there are also periodic fluctuations in sea temperature. For example, the 11-year sunspot cycle causes sea temperatures to rise after an 11-year gap.

- **Sea Surface Temperature:** The surface temperature of oceans is represented graphically by isotherms, which show a decrease in temperature from the equator to the poles. However, the highest sea surface temperature is observed not exactly at the equator but slightly to the north of the equator due to the presence of more land area north of 0° latitude.
  Water bodies in the southern hemisphere generally have higher average temperatures than those in the northern hemisphere because the greater proportion of land area in the northern hemisphere absorbs more solar energy than water. Moreover, due to the presence of continents in the northern hemisphere, the circulation of water and heat transport is less efficient than in the southern hemisphere.
- **Horizontal Distribution of Temperature:** The horizontal temperature distribution is shown by isothermal lines, i.e., lines joining places of equal temperature. In the Atlantic Ocean, for example, the isothermal lines in February reveal that the lines are closely spaced south of Newfoundland, near the west coast of Europe and the North Sea, and then widen out and bulge toward the north near the coast of Norway.

This phenomenon is caused by the cold Labrador Current flowing southward along the North American coast, which reduces the temperature of the region more sharply than in other places at the same latitude. At the same time, the warm Gulf Stream moves toward the western coast of Europe, raising the temperature of the west coast of Europe.

- In the southwestern part of the Atlantic, isotherms bulge southwestward due to the warm Brazil current, while in the eastern part of the South Atlantic, isotherms bend northwestward due to the cold Benguela current. Further south, isotherms are parallel due to the constant prevailing west wind drift.
- Temperature distribution in the North and South Atlantic is not symmetrical. For example, the 5°C isotherm touches 70°N latitude in the North Atlantic, whereas it never crosses 50°S latitude in the South Atlantic because the warm Gulf Stream is more powerful and reaches a higher latitude than the cold Brazil current. There is also a significant difference between the eastern and western parts of the Atlantic. In the western part near the Labrador coast, 0°C temperature is recorded, but 9° to 13°C temperature is found on the west coast of Europe.
- In marginal seas, temperature varies due to latitude and location. For example, the Mediterranean has higher temperatures than the neighboring Atlantic Ocean, but the Baltic and Hudson Bay are colder than the Atlantic.
- In the northern half of the Pacific, isotherms and latitudes are almost parallel. However, on the coast of North America, isotherms bend slightly northward under the influence of the warm Kuroshio current, and along the coast of Japan, isotherms are closely spaced due to the cold Oyashio current.
- In the equatorial region of the western part of the Pacific, high temperatures are recorded as the warm equatorial current flows southward. In the eastern part of the Pacific, low temperatures prevail due to the influence of the cold Peru Current. In the South Pacific, isotherms make minor loops due to the warm Peru or Humboldt Current.
- In the Indian Ocean, the isotherms of 25°C, 27°C, and 28°C occupy the central location of the ocean. There is no significant difference between the southern Indian Ocean and the southern Pacific Ocean, as the isotherms roughly follow the parallels, except for a minor loop near the Cape of Good Hope due to the cold Agulhas current. The isotherms bend southward near the coast of North Africa due to a cold current flowing southwestward from Cape Guardafui.
- The same isotherm bends northward in the Arabian Sea when it enters the Indian Peninsula, but in the Bay of Bengal, it bends southward due to the effect of monsoon drift. Enclosed water bodies like the Red Sea have higher temperatures toward the south due to the mixture of open ocean water. The Persian Gulf records lower temperatures than the Indian Ocean under the influence of cold land area.
- In August, the isothermal conditions are markedly different from those in February. In the Atlantic, the Arctic ice melts away, resulting in a northward shift of all isotherms in the Davis Strait. The sharp northward bends of isotherms on the Norwegian coast are absent in August. On average, the isotherms in the North Atlantic shift northward in August. The southern Pacific Ocean shows isothermal lines and latitudes placed parallel to each other. Towards the west, the adjacent ocean of the Australia-Asia region witnesses temperatures as high as

28°C as the westerly flowing equatorial current draws warm water toward the western Pacific.

- In the Indian Ocean, the highest surface temperature of 28°C is recorded over the Arabian Sea and the Bay of Bengal. In August, enclosed seas like the Red Sea and the Persian Gulf show higher temperatures (30° to 33°C) than the open ocean due to their contact with warm land areas.

Vertical Distribution of Temperature

- The temperature of the ocean water changes as you go deeper, typically decreasing as you descend. About 90% of the sun's heat is absorbed within the top 60 feet (15.6 meters) of water. The water's temperature generally matches the surface temperature up to a depth of around 100 meters, but it tends to decrease with further depth.
- In tropical oceans and seas, there are three distinct layers of water temperature from the surface to the bottom. The first layer is approximately 500 meters thick, with temperatures ranging from 20°C to 25°C. In mid-latitude regions, this top layer is only present during the summer months. The second layer, known as the thermodine layer, is located just below the first one.
- This layer is characterized by a rapid decrease in temperature as depth increases. The third and final layer is very cold and extends all the way down to the ocean floor.

Salt Budget

The salt budget, also known as the salt cycle, encompasses the various processes by which salt travels between the ocean, the lithosphere (Earth's solid outer layer), and to a lesser extent, the atmosphere.

- The movement of water, including groundwater, dissolves minerals from rocks through surface erosion. This mineral-rich water then flows into rivers and streams, eventually making its way to the ocean and contributing to its salinity. Over time, some of the salts in the ocean water settle to the bottom through sedimentation, forming mineralized rocks. These rocks can be raised above the ocean surface over millions of years due to plate tectonics or volcanic activity, reintroducing the salt to the lithosphere in the form of minerals (rocks).
- Additionally, ocean salt can be transferred to the atmosphere through the action of wind, creating salt spray. This salt then falls back to the lithosphere, mixed with precipitation. However, this process accounts for only a small portion of the salt exchange between land and sea.
- Overall, the salt cycle operates over an extensive period of time, involving the continuous transfer of salt between the ocean, lithosphere, and atmosphere.

What is the main factor responsible for the highest sea surface temperatures being found slightly north of the equator?

A. The presence of more land area north of 0° latitude

B. The influence of ocean currents such as the Gulf Stream

C. The presence of large continental ice sheets in the southern hemisphere

D. The influence of the Earth's axial tilt

Conclusion

The sun is the primary source of heat for the world's oceans, with additional contributions from the Earth's interior. Heat is transferred through various mechanisms such as absorption of solar radiation, convection currents, and friction from winds and currents. The oceans lose heat through back radiation, heat exchange with the atmosphere, and evaporation. The distribution of ocean temperatures varies depending on factors such as latitude, ocean currents, and prevailing winds. The salt budget, or salt cycle, involves the continuous transfer of salt between the ocean, lithosphere, and atmosphere, affecting the ocean's salinity and overall chemical composition.

What is the primary source of heat for the world's oceans?

The primary source of heat for the world's oceans is the sun, which provides energy not only for the oceans but for all life on Earth. Additionally, heat from the Earth's interior also contributes to warming the ocean water.

How is heat transferred within the ocean?

Heat is transferred within the ocean through absorption of solar radiation, convection currents, and friction from winds and currents.

How do the oceans lose heat?

The ocean loses heat through back radiation, heat exchange with the atmosphere, and evaporation.

What factors influence the temperature range and distribution in the oceans?

The temperature range and distribution in the oceans are influenced by the annual variation in solar radiation, the nature of ocean currents, the prevailing winds, and the location of landmasses.

What is the salt budget, and how does it operate?

The salt budget, also known as the salt cycle, encompasses the various processes by which salt travels between the ocean, the

lithosphere (Earth's solid outer layer), and to a lesser extent, the atmosphere. The salt cycle operates over an extensive period of time, involving the continuous transfer of salt between the ocean, lithosphere, and atmosphere through processes such as erosion, sedimentation, and plate tectonics.

1. What is the source of heat in the oceans?

Ans. The primary source of heat in the oceans is solar radiation. Sunlight penetrates the Earth's atmosphere and warms the surface of the ocean. This heat is then distributed throughout the ocean through various processes such as conduction, convection, and radiation.

2. What is the heat budget of the oceans?

Ans. The heat budget of the oceans refers to the balance between the incoming and outgoing heat in the ocean system. It takes into account factors such as solar radiation, heat exchange with the atmosphere, heat transported by ocean currents, and heat released or absorbed during various oceanic processes. Understanding the heat budget is crucial for studying the Earth's climate system and predicting changes in ocean temperatures.

3. What is the salt budget of the oceans?

Ans. The salt budget of the oceans refers to the balance between the input and output of salt in the ocean system. It involves processes such as the addition of salt through river runoff and precipitation, the removal of salt through evaporation and sea ice formation, and the transport of salt by ocean currents. The salt budget plays a significant role in regulating the salinity of the oceans, which affects ocean circulation and marine ecosystems.

4. How do heat and salt budgets affect ocean currents?

Ans. Heat and salt budgets play a crucial role in driving ocean currents. Differences in temperature and salinity create density gradients in the ocean, which lead to the formation of currents. Warmer and less salty water tends to rise, while colder and saltier water sinks, creating vertical circulation. These vertical movements, in turn, drive horizontal ocean currents. Changes in the heat and salt budgets can alter the density patterns and thus impact the strength and direction of ocean currents.

5. How do heat and salt budgets contribute to climate change?

Ans. Changes in the heat and salt budgets of the oceans can have significant implications for climate change. As the oceans absorb excess heat from the atmosphere, they act as a heat sink, buffering the effects of global warming. However, increased heat absorption can lead to thermal expansion of seawater and contribute to sea-level rise. Changes in the salt budget can also affect ocean circulation patterns, which play a crucial role in redistributing heat around the planet. Understanding and monitoring heat and salt budgets are essential for assessing the impacts of climate change on the oceans and predicting future climate scenarios.

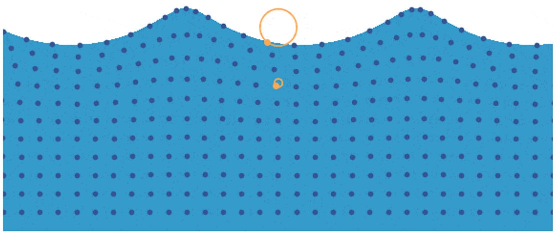
Waves, Currents & Tides

Ocean Waves

- A wave is a rhythmic movement that transfers energy through matter or space. In the context of ocean waves, this refers to the undulating motion of the water's surface.
- Waves are characterized by oscillatory movements that cause the water surface to rise and fall. They are a form of horizontal motion in ocean water. However, it is important to note that it is the energy, rather than the water itself, that moves across the ocean's surface. This energy is primarily supplied by the wind.
- As a wave progresses, each water particle moves in a circular pattern. There are two main components to a wave: the elevated part, known as the crest, and the low point, referred to as the trough.

Friction from the wind moving over the water causes the water to move along with the wind. If the wind speed is high enough, the water begins to pile up and a wave is formed.

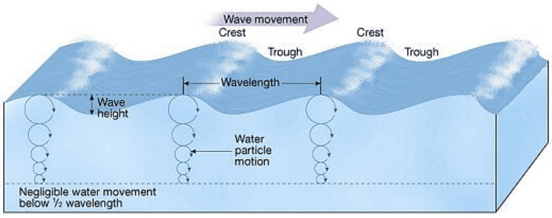
As wind velocity increases: Wavelength, Wave period, Height Increase.

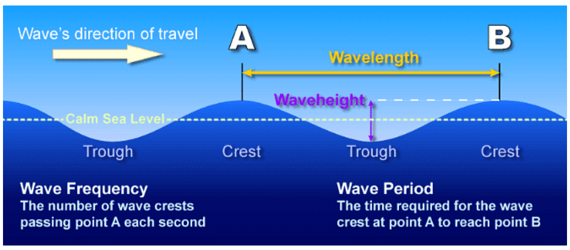


Wave Motion

The diameter of the orbit: **increases with increasing wave size**.

The diameter of the orbit: **decreases with depth below the water surface**.

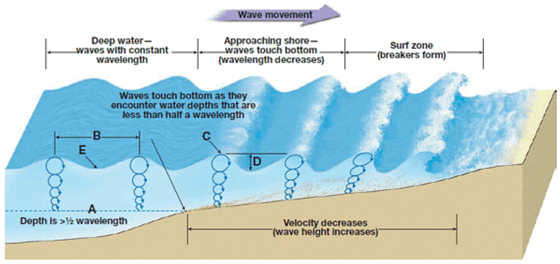




Ocean Wave Description

Wave crest and trough	The **highest point** of a wave is called crest. The **lowest point** of a wave is called trough.
Wave height	It is the perpendicular **distance from the bottom of a trough to the top of a crest** of a wave.
Wave amplitude	It is **one-half of the wave height.**
Wave period	It is merely the **time interval between two successive wave crests** or troughs as they pass a fixed point.
Wavelength	It is the horizontal **distance between two successive crests.**
Wave speed	It is the rate at which the wave moves through the water. It is **measured in knots.**
Frequency	the number of complete waves (or oscillations) that occur over a given period of time. Usually measured in **cycles per second.**

Most of the waves present on the ocean's surface are wind-generated waves.



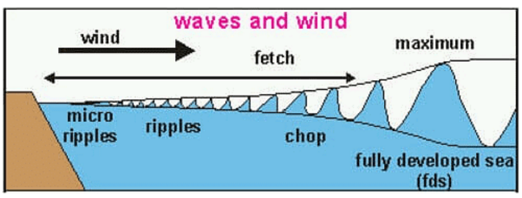
Wave Motion and Diameter

As the wave slows, its crest and trough come closer together. The top of the wave is not slowed by friction and moves faster than the bottom.

Wave Types

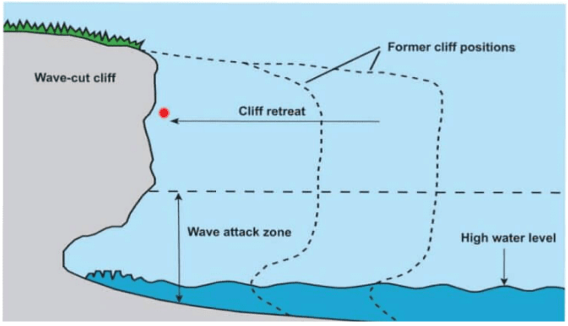
Type of Wave	Period	Wavelength	Depth of influence	Source
Capillary or ripple	< 1 second	< 2 cm	Very shallow	Light wind, insects
Chop	1-10 seconds	1-10 m	Shallow	Strong wind
Swell	10-30 seconds	up to 100 m	½ of the wavelength	Storms
Tsunami	5-90 minutes	20 km to 300+ km	To the bottom	Earthquakes, Landslides, Volcanic eruptions, and more

Ocean Wave Types



Waves And Wind

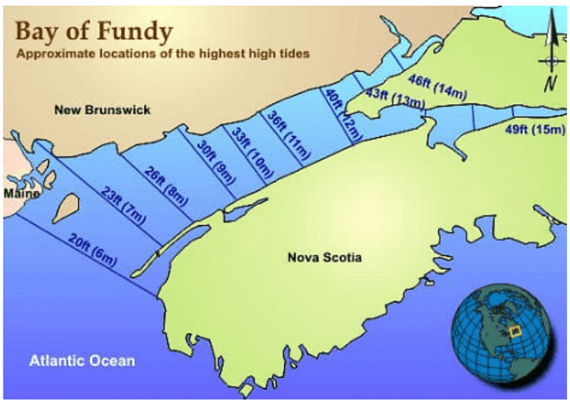
Wave Cut action



Wave Cut Action

Tides

- Tides refer to the periodic short-term fluctuations in sea levels, primarily caused by the gravitational interactions between the Earth, Moon, and Sun. The Moon, being closer to the Earth, has a more significant influence on tides than the Sun. The Earth's rotation also contributes to the formation of tides.
- The primary causes of tides are the gravitational pulls from the Moon and, to a lesser extent, the Sun. Additionally, a centrifugal force that acts in opposition to the Earth's gravitational pull also affects tides. The balance between these forces results in the formation of tides.
- High tides occur when the crest, or the highest part of a wave, reaches a specific location, while low tides correspond to the trough, or the lowest part of the wave. The tidal range represents the difference in height between high and low tides.
- The world's highest tide occurs in the Bay of Fundy (Canada). In India, the highest tide is recorded at Okha, Gujarat. The largest tidal range globally is found at the upper end of the Bay of Fundy in eastern Canada, where it is common to observe water level fluctuations of up to 15 meters (50 feet) twice a day. This phenomenon also results in a tidal bore—a wall of seawater ranging from several centimeters to over a meter in height—that rushes up the Petitcodiac River in New Brunswick, covering many kilometers.



Bay of Funday

Tide changes proceed via the following stages:

- Sea level rises over several hours, covering the intertidal zone; **flood tide**.
- The water rises to its highest level, reaching **high tide**.
- Sea level falls over several hours, revealing the intertidal zone; **ebb tide**.
- The water stops falling, reaching **low tide**.

Tidal streams refer to the oscillating currents created by the changing tides. When the tidal current comes to a halt, it is known as slack water or slack tide. At this point, the tide changes direction, which is referred to as "turning." Slack water typically takes place close to high and low water times. However, in some locations, the timing of slack tide may differ from high and low water.

Tides usually have a semi-diurnal cycle (two high tides and two low tides per day) or a diurnal cycle (one complete tidal cycle per day). On any given day, the two high tides may not be of equal height, which is referred to as the daily inequality. As a result, tide tables indicate a higher high water and a lower high water level. Similarly, the two daily low tides consist of a higher low water and a lower low water level. The daily inequality varies and is generally minimal when the Moon is positioned above the equator.

Which of the following ocean currents is a cold current? A. Gulf Stream **B.** Kuroshio Current **C.** Benguela Current **D.** East Australian Current

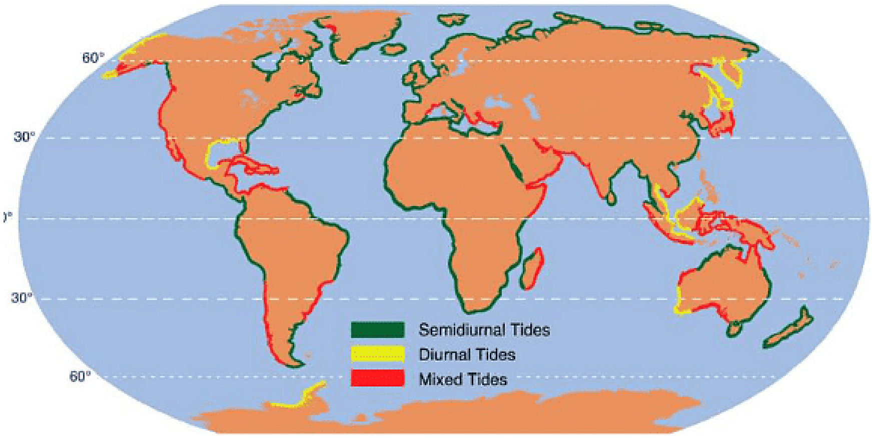
Types of Tides

Tides vary in their frequency, direction and movement from place to place and also from time to time.

Tides may be grouped into various types based on their frequency of occurrence in one day or 24 hours or based on their height.

Tides based on Frequency

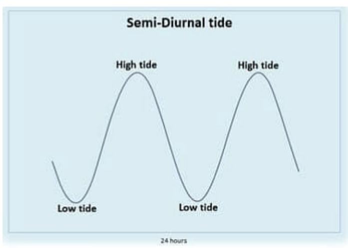
- Semi-diurnal tide
- Diurnal tide
- Mixed tide



•

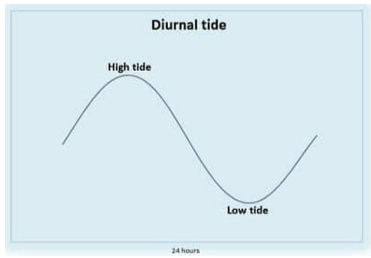
Semi-Diurnal Tide

- The most common tidal pattern consists of two high tides and two low tides each day, with variations ranging from 3 to 4 tides in certain cases. Typically, the heights of consecutive high or low tides are roughly the same.
- Tides occur at regular intervals of 12 hours and 25 minutes, rather than exactly 12 hours. This is due to the moon's orbit around the Earth, as it moves from west to east. The moon's position relative to the Earth shifts slightly to the east each day when observed from the same location at the same time. This time lag is responsible for the 12-hour and 25-minute interval between tides, which occur twice daily.
- In Southampton, England, tides occur 6-8 times per day. This is due to the combined effects of the North Sea and English Channel, which push water at different intervals. Southampton experiences 2 high tides from the North Sea, 2 high tides from the English Channel, 2 neap tides from the North Sea, and 2 neap tides from the English Channel.



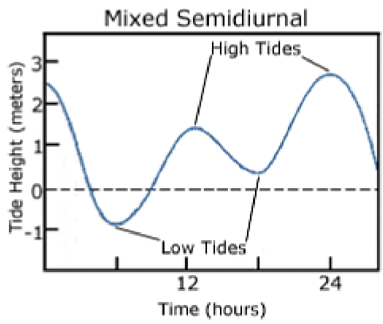
Diurnal Tide

- Each day, there is a single high tide and a single low tide, with both of these tides having roughly the same height. Essentially, the ocean level rises once and falls once in a 24-hour period, with the difference in water levels remaining fairly consistent.



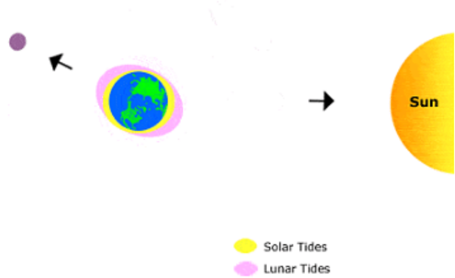
Mixed Tide

- Mixed tides refer to the fluctuations in tidal heights, often seen along the western coast of North America and numerous islands in the Pacific Ocean. These variations in tidal height make the tides appear irregular, resulting in a combination of higher and lower tides.



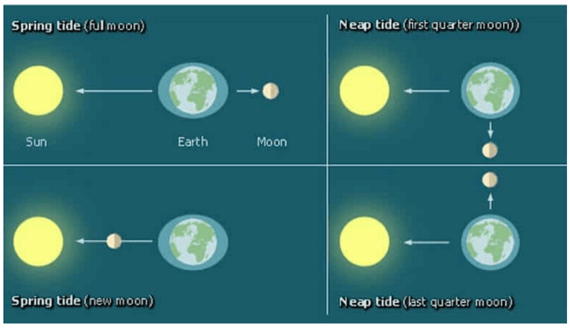
Tides based on the Sun, Moon and the Earth Positions

The height of rising water (high tide) varies appreciably depending upon the position of the sun and moon with respect to the earth. **Spring tides** and **neap tides** come under this category.



Spring Tides

- The height of tides on Earth is influenced by the positions of the sun and the moon relative to our planet. When these three celestial bodies align in a straight line, known as a syzygy, the resulting tides are higher than usual.
- These heightened tides, called spring tides, occur twice a month - once during the full moon phase and again during the new moon phase.

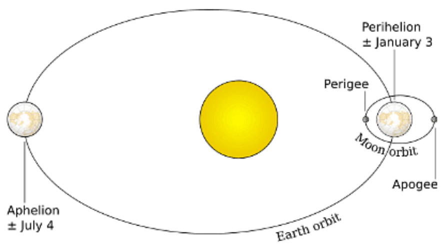


Neap Tides

- Neap tides occur when the Moon is in its first or third quarter phase, causing the Sun and Moon to be separated by 90° when observed from Earth. During this time, the Sun's tidal force partially counteracts the Moon's tidal force. Although the Moon's gravitational pull is more than twice as strong as the Sun's, its influence is reduced due to the opposing force of the Sun's gravity.
- The term "neap" is derived from an Anglo-Saxon word meaning "without power," which is fitting as the tidal range is at its minimum during this period. Neap tides, also known as "neaps," typically occur twice a month, with a seven-day interval between spring tides and neap tides.

The Magnitude of Tides based on Perigee and Apogee of Moon

- Once in a month, when the moon's orbit is closest to the earth **(perigee)**, unusually high and low tides occur. During this time the tidal range is greater than normal.
- Two weeks later, when the moon is farthest from earth **(apogee)**, the moon's gravitational force is limited and the tidal ranges are less than their average heights.



Magnitude of tides based on Perigee and Apogee of earth

- The magnitude of tides is influenced by the Earth's proximity to the sun and the moon. When the Earth is closest to the sun, known as perihelion, which occurs around January 3rd each year, the tidal ranges are much greater, resulting in unusually high and low tides. On the other hand, when the Earth is farthest from the sun, called aphelion, which occurs around July 4th each year, the tidal ranges are smaller than average. Apogee refers to the point in an orbit around the Earth that is furthest from the Earth, while aphelion is the point in the elliptical orbit of a celestial body where it is farthest from the sun.
- Tides are important for various reasons, particularly because they can be accurately predicted due to the known positions of the Earth, moon, and sun. This allows navigators and fishermen to plan their activities accordingly.
- Navigation is significantly impacted by tidal heights. Harbors situated near rivers and within estuaries with shallow bars at their entrances require high tides for ships and boats to enter safely. High tides raise the water level near the shore, making it easier for ships to arrive at the harbor.
- Additionally, tides can make certain rivers navigable for ocean-going vessels, contributing to the development of important ports. For example, the tidal nature of the Thames and Hooghly rivers has allowed London and Kolkata (formerly Calcutta) to become significant ports. In summary, the Earth's position relative to the sun and the moon affects the magnitude of tides, which play a crucial role in navigation and the establishment of key ports.

Fishing

- The high tides also help in fishing. Many more fish come closer to the shore during the high tide. This enables fishermen to get a plentiful catch.

Desilting

- Tides are also helpful in desilting the sediments and in removing polluted water from river estuaries.

Other

- Tides are used to generate electrical power (in Canada, France, Russia, and China).
- A 3 MW tidal power project was constructed at **Durgaduani in Sunderbans of West Bengal**.

Characteristics of Tides

Tides are characterized by various factors, such as their height, strength, and intensity, which are influenced by geographical features and locations.

- On broad continental shelves, tidal bulges tend to be higher due to the shape and size of the shelf. In contrast, tidal currents are generally weaker in the open ocean, where there is less resistance from landforms.
- When tidal bulges reach mid-oceanic islands, their height tends to decrease due to the smaller area and less resistance offered by the island. The shape of bays and estuaries along coastlines can also affect the intensity of tides, with many resulting in stronger tides.
- Funnel-shaped bays, in particular, can greatly alter tidal magnitudes. The Bay of Fundy is a prime example of this, as it has the highest tidal range in the world. However, the large continents on Earth obstruct the westward movement of tidal bulges as the planet rotates, causing variations in tidal patterns.
- As a result of these factors, tides differ significantly between oceans and locations, making them complex and diverse phenomena.

Tidal bore

- A tidal bore is a large wave that occurs when the spring tide enters a long, narrow, and shallow inlet. The wave is generated due to the constriction of the tidal forces and turbulence in the whelps, resulting in a rumbling roar. High tides can also happen in gulfs, particularly in those with wide fronts and narrow rears.
- The movement of water into and out of a gulf through channels is referred to as a tidal current. When a tidal wave enters the narrow and shallow estuary of a river, the front of the wave appears vertical because the river water piles up against the tidal wave, and the friction of the river bed is present. This steep-nosed tidal crest looks like a vertical wall of water rushing upstream and is called a tidal bore.
- Several factors contribute to the formation of tidal bores, including the strength of the incoming tidal wave, the width and depth of the channel, and the river flow. However, there are exceptions, such as the Amazon River, which is not narrow but still experiences a strong tidal bore due to its shallow mouth with numerous low-lying islands and sandbars.
- In India, tidal bores are commonly observed in the Hooghly River, while the most powerful tidal bores occur in the Qiantang River in China. The term "bore" comes from the sound the tidal current makes when traveling through narrow channels.
- Tidal bores occur in relatively few locations worldwide, typically in areas with a large tidal range of more than 6 meters (20 ft) between high and low water. These bores usually happen during the flood tide and seldom during the ebb tide. Additionally, tidal bores almost never occur during neap tides, which are the weakest tides that take place during the quarter moon phases.

Impact of Tidal Bore

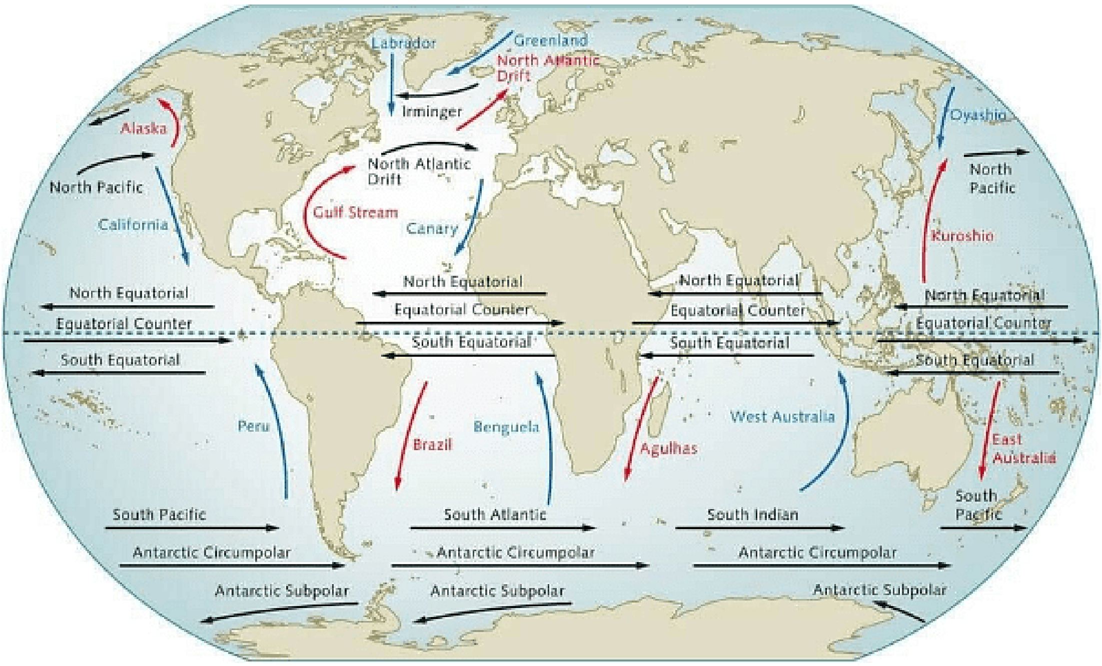
- The impact of tidal bores can be significant and varies in different aspects. While tides are stable and predictable, tidal bores are less so, making them potentially dangerous.
- In terms of shipping and navigation, tidal bores can pose challenges in estuarine zones. Bores of considerable magnitude have the potential to capsize boats and large ships, causing disruptions to maritime activities.
- Fishing zones in estuaries and gulfs can also be negatively affected by strong tidal bores. These areas, which are crucial for the sustenance of various wildlife species, can experience disruptions in their ecological balance.
- The environment near the river mouth can be adversely impacted by tidal bores as well. Estuaries influenced by tidal bores serve as essential feeding and breeding grounds for numerous forms of wildlife. When these bores occur, animals can be caught in the leading edge of the tidal wave and become buried in the silty water. As a result, carnivores and scavengers are often seen following tidal bores, contributing to the ecological impact.
- In summary, tidal bores can have negative effects on shipping, navigation, fishing, and the ecology of river mouths and estuaries. These unpredictable events can be dangerous and disruptive for both human activities and the natural environment.

Ocean Currents

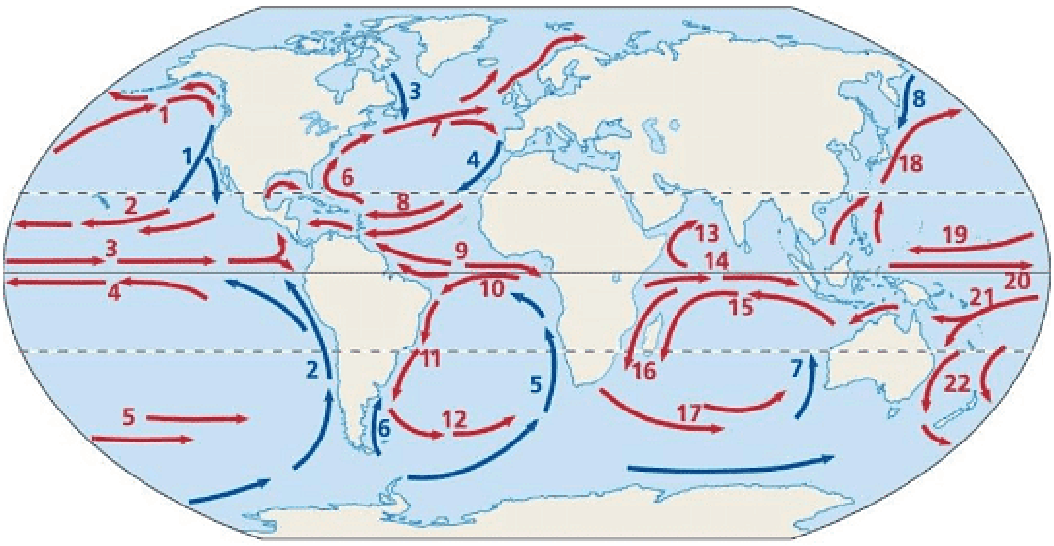
- Ocean currents refer to the continuous, general movement of ocean water in a specific direction, similar to a river flowing over the ocean's surface. Approximately 10% of the world's ocean water is involved in surface currents, which primarily move water horizontally and vertically in the top layer above the thermocline, the layer where temperature changes rapidly. The water below the

thermocline also circulates, but the movement is much slower.

- The heat budget of the Earth varies across latitudes, with a surplus of heat in the tropics and a deficit in the polar regions (beyond 40 degrees N and S). Weather phenomena and circulation patterns help to transfer heat from the tropics towards the poles, maintaining the Earth's heat balance. Ocean currents play a significant role in this process.
- Ocean currents can be classified as warm or cold currents, depending on their impact on the destination region rather than their absolute temperature. A warm current is one that moves towards the poles in both hemispheres, carrying warm water from lower latitudes to higher latitudes. In contrast, a cold current originates from higher latitudes and moves towards the tropics, bringing cooler water to those regions.



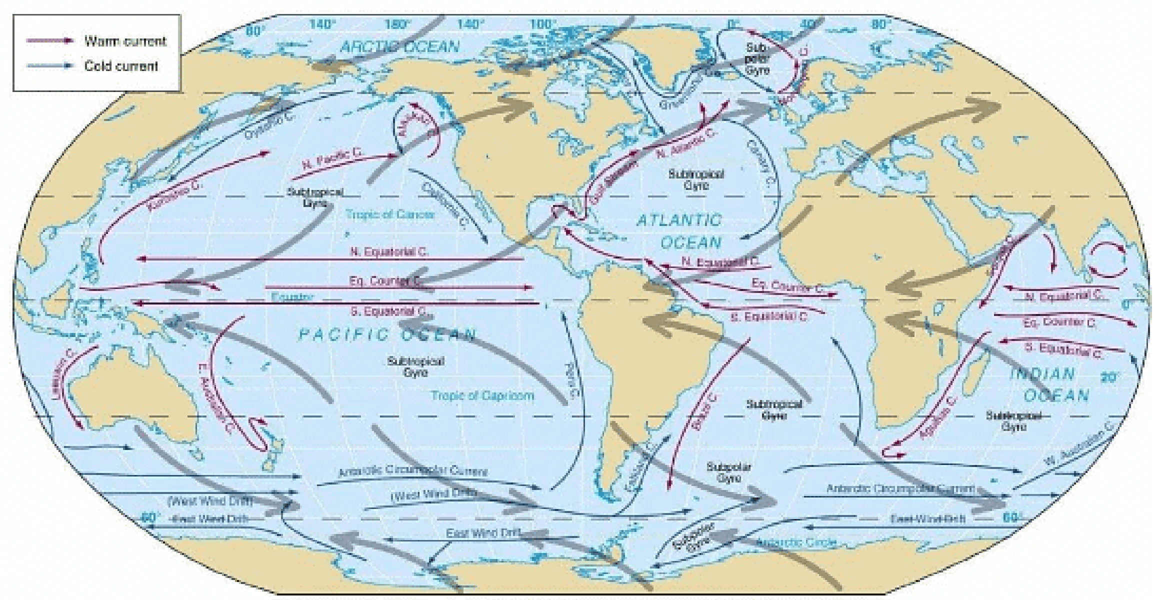
-
- In prelims, a question can be asked on the character of the ocean currents. Ocean currents will be numbered as 1,2,3 and 4 and it will be asked whether they are cold or warm, or which of them are cold/warm. Now you don't need to know the name of those currents, they can be hypothetical also, just by seeing the direction of the flow of ocean currents; you will be able to answer that.



-

- In the above map, if you see, c**urrent (1) and (6) are in the same latitudes but because of their direction of motion, they are categorized as cold and warm**.

Note: There are some exceptions to this general rule. Kindly check the important ocean currents from a World Map.



Types of Ocean Currents

1. Based on Depth

The ocean currents may be classified based on their depth as **surface currents** and **deep water currents:**

- **surface currents** constitute about **10 percent of all the water in the ocean**, these waters are the upper 400 m of the ocean;
- **deep water currents** make up the other **90 percent of the ocean water**. These waters move around the ocean basins due to variations in density and gravity.
  (i) The **density difference is a function of different temperatures and salinity**
  (ii) These **deep waters sink into the deep ocean basins at high latitudes where the temperatures are cold enough to cause the density to increase.**

2. Based on Temperature

Ocean currents are classified based on temperature: as **cold currents** and **warm currents**:

- **Cold currents** bring **cold water into warm water areas [from high latitudes to low latitudes].** These currents are usually found on the **west coast of the continents** (currents flow in the clockwise direction in the northern hemisphere and in anti-clockwise direction in the southern hemisphere) in the low and middle latitudes (true in both hemispheres) and on the east coast in the higher latitudes in the Northern Hemisphere;
- **Warm currents** bring **warm water into cold water areas[low to high latitudes]** and are usually observed on the east coast of continents in the low and middle latitudes (true in both hemispheres). In the northern hemisphere, they are found on the west coasts of continents in high latitudes.

Forces Responsible For Ocean Currents

1. Primary Forces

Influence of insolation

- Heating by solar energy causes the water to expand. That is why, near the equator the ocean water is about 8 cm higher in level than in the middle latitudes.
- This causes a very slight gradient and water tends to flow down the slope. The flow is normally from east to west.

Influence of wind (atmospheric circulation)

- The influence of wind on atmospheric circulation plays a significant role in the movement of ocean waters. When wind blows across the ocean surface, it causes the water to move due to the friction between the wind and the water surface. The force and direction of the wind, combined with the Coriolis effect, determine the magnitude and direction of ocean currents. A prime example of this is the seasonal reversal of ocean currents in the Indian Ocean, which is caused by monsoon winds.

- The patterns of oceanic circulation generally correspond to those of Earth's atmospheric circulation. In the middle latitudes, air circulation over the oceans is predominantly anticyclonic, meaning that it revolves around a high-pressure center. This pattern is more pronounced in the Southern Hemisphere than in the Northern Hemisphere due to differences in the extent of landmass. Consequently, oceanic circulation patterns in these regions also follow this anticyclonic pattern.
- In higher latitudes, wind flow is primarily cyclonic, which means that it revolves around a low-pressure center. This pattern is found in the sub-polar low-pressure belt, and oceanic circulation in these areas also reflects this cyclonic pattern.
- In regions with prominent monsoonal flows, such as the northern Indian Ocean, monsoon winds greatly influence the movement of ocean currents. These currents change direction according to the seasonal shifts in wind patterns. Overall, wind plays a crucial role in shaping the circulation patterns of both the atmosphere and the oceans.

Influence of Gravity

- Gravity tends to pull the water down to pile and create **gradient variation**.

Influence of Coriolis Force

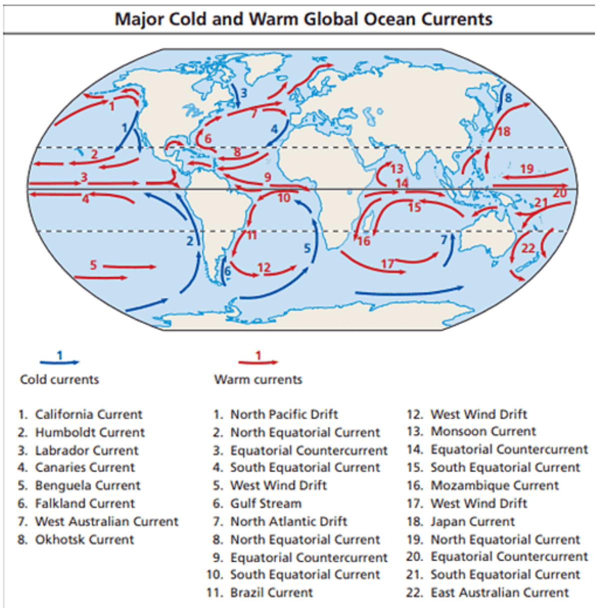
- The Coriolis force intervenes and causes the water to move to the **right** in the northern hemisphere and to the **left** in the southern hemisphere.
- These large accumulations of water and the flow around them are called **Gyres**. These produce large circular currents in all the ocean basins. One such circular current is the **Sargasso Sea**.

2. Secondary Forces

- Secondary forces, such as temperature and salinity differences, play a significant role in shaping ocean currents. These differences in water density greatly influence the vertical movement of currents, known as vertical currents.
- The density of water is affected by its salinity and temperature. Highly saline water is denser than water with low salinity, and cold water is denser than warm water. As a result, dense water tends to sink, whereas lighter water tends to rise.
- Cold-water ocean currents develop when the dense, cold water near the poles sinks and gradually moves toward the equator. In contrast, warm-water currents originate at the equator, where the lighter, warm water flows along the surface towards the poles, replacing the sinking cold water.
- In summary, temperature and salinity differences in ocean water create density variations that drive the vertical movement of ocean currents. Cold-water currents form when dense, cold water sinks and moves from the poles to the equator, while warm-water currents flow from the equator towards the poles, replacing the sinking cold water.

Important Ocean Currents

It is important for you to remember cold and warn ocean currents.



NOTE- Major Fishing grounds of the World exist where warm and cold Ocean Current meets.

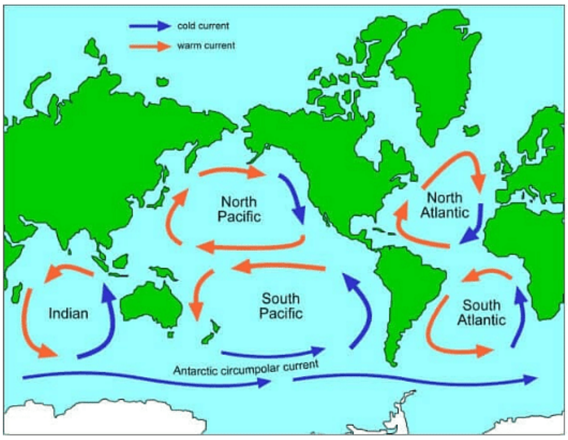
Causes of Ocean Currents

1. Planetary Winds

Planetary winds play a vital role in the formation and sustenance of ocean currents. Since planetary winds blow with consistency, over the surface of the ocean, they tend to push the water in one direction because of friction. This is the main cause of the flow of water.

Because of the Coriolis Effect, in the Northern Hemisphere currents flow to the right of the wind direction while in the Southern Hemisphere, winds blow to the left. Intervening continents and basin topography often block the continuous flow of the water and often deflect the moving water in a circular pattern. This circular motion of water along the

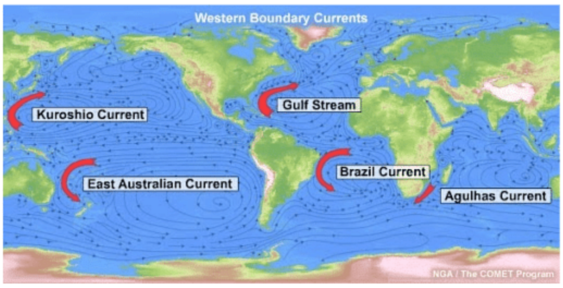
periphery of the ocean basin is called Gyre. The following Map will broadly show the formation of different gyres in Oceans.



2. Effect of the Temperature

There are marked variations in the horizontal and vertical distribution of the temperatures in the ocean. In general, the temperature decreases as we move towards the pole from the equator.

There is an inverse relationship between temperature and density of the water i.e. higher the temperature, the lower will be its density. As a result, the warm and low-density water from the equatorial region moves towards the colder polar waters. Contrary to this there is a movement of ocean water below the water surface in the form of subsurface current from colder polar areas to warmer equatorial area. The Gulf Stream and Kuroshio Current (warm) are very good examples of this.



3. Salinity

- The salinity levels in the ocean can differ depending on the location. Water that has a higher salinity is denser compared to water with lower salinity. This difference in density leads to the creation of ocean currents, which typically flow from areas of low salinity to areas of high salinity.
- For instance, ocean currents can be observed moving from the open ocean towards inland seas, such as the current that flows from the Atlantic Ocean into the Mediterranean Sea. Similarly, there is a current that flows from the Indian Ocean into the Red Sea through the Bab Al Mandab strait. The Peru Current is another example of a current that is generated due to variations in water density caused by differences in salinity.

4. Rotation of Earth

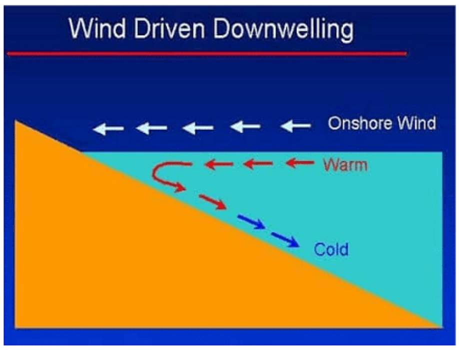
- The Coriolis force is a deflective force caused by the Earth's rotation from west to east on its axis. This force influences the direction of ocean currents, causing them to veer towards the right in the Northern Hemisphere and towards the left in the Southern Hemisphere. As a result, ocean currents form a clockwise circulation in the Northern Hemisphere and a counterclockwise circulation in the Southern Hemisphere. These large circular patterns are known as gyres.
- The North Atlantic Gyre is particularly notable because it traps water within its circulating currents, creating a stagnant body of water known as the Sargasso Sea. This sea, named after the Sargassum weed found within it, is unique because it is the only sea located entirely within an ocean. The Sargassum weed is an endemic vegetation found exclusively in the Sargasso Sea, which is an internationally protected area.

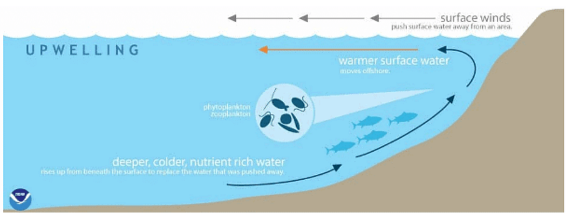
5. Configuration of the Coastline

Coastline plays an important role in governing the direction of the flow of the ocean current. For example, the equatorial current after being obstructed by the Brazilian coast is bifurcated into two branches. The Northern Branch is called the Caribbean current while the Southern branch is called the Brazilian current.

Note: After hitting a coastline, apart from moving towards North and South, some of the water also moves downward, this is called Downwelling.

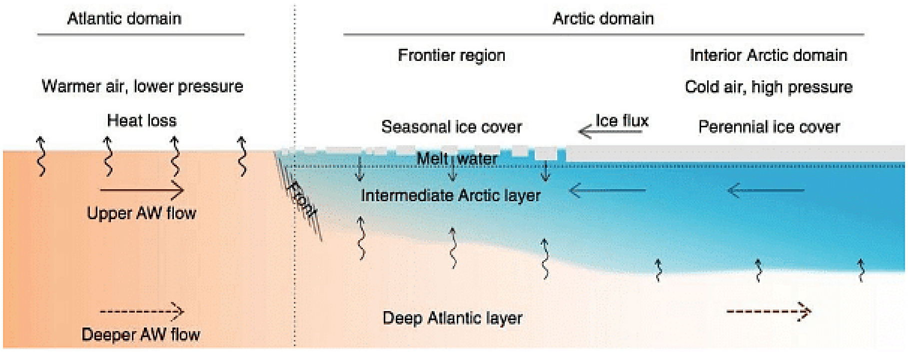
This water penetrates deep in the ocean and moves parallel to the surface current as an undercurrent and comes out on the other side of the ocean as upwelling. Since this upwelling water comes out from the depth, it is relatively cold and brings a lot of nutrients to the surface. Regions, where upwelling is present, are rich fishing grounds e.g. Peru coast.





Desert Formation and Ocean Currents

- Major hot deserts are located between 20-30 degree latitudes and on the western side of continents because of the effects of off-shore Trade Winds, which is why they are also called Trade Wind Deserts. These deserts, such as the Sahara, the Great Australian Desert, the Arabian Desert, the Iranian Desert, the Thar Desert, the Kalahari Desert, and the Namib Desert, are situated along the Horse Latitudes or the Sub-Tropical High-Pressure Belts where the air descends, creating conditions that make precipitation unlikely.
- The rain-bearing Trade Winds blow off-shore, and the Westerlies, which blow onshore, remain outside the desert limits. Consequently, the winds that reach the deserts blow from cooler to warmer regions, lowering their relative humidity and making condensation almost impossible. The absence of clouds in the sky and the low relative humidity result in the evaporation of any moisture, creating regions of permanent drought.
- On the western coasts, cold currents produce mists and fogs by chilling the incoming air. As this air warms up when it comes into contact with hot land, little rain falls. The desiccating effect of cold currents, such as the Peruvian Current along the Chilean coast, is so strong that the mean annual rainfall in the Atacama Desert is no more than 1.3 cm.
- "**Atlantification**" is a process where warmer water from the Atlantic Ocean flows into the Arctic at the Barents Sea. This warmer, saltier Atlantic water is typically deeper under the more buoyant Arctic water at the surface. However, the Atlantic water has been rising recently, causing the heat in the Atlantic water to prevent ice formation and melt existing sea ice from below. As a result, the ice is now being affected both from the top by a warming atmosphere and at the bottom by a warming ocean.



What is the primary cause of tides in the Earth's oceans? A. Wind **B.** Ocean currents **C.** Earth's rotation **D.** Gravitational forces of the Moon and the Sun

Conclusion

Ocean waves, tides, and currents play crucial roles in shaping the Earth's climate, navigation, fishing, and overall marine ecosystem. The interactions between the Earth, Moon, and Sun, as well as factors such as wind, temperature, salinity, and the Earth's rotation, contribute to the formation and characteristics of these oceanic phenomena. Understanding and predicting these oceanic movements are essential for the safety of maritime activities and the conservation of marine life. Moreover, the study of ocean currents and tides provides valuable insights into the Earth's heat budget, climate patterns, and the distribution of nutrients in the ocean, all of which are vital for maintaining the delicate balance of our planet's ecosystems.

What are the primary forces responsible for the formation of ocean currents?

The primary forces responsible for the formation of ocean currents are the influence of insolation (solar radiation), the influence of wind (atmospheric circulation), gravity, and the Coriolis force due to the Earth's rotation.

What is the difference between warm and cold ocean currents?

Warm ocean currents are those that move from lower latitudes (near the equator) towards higher latitudes (towards the poles), carrying warm water to colder regions. Cold ocean currents, on the other

hand, originate from higher latitudes and move towards the tropics, bringing cooler water to warmer regions.

What is a tidal bore and where do they occur?

A tidal bore is a large wave that occurs when the spring tide enters a long, narrow, and shallow inlet. The wave is generated due to the constriction of the tidal forces and turbulence in the whelps, resulting in a rumbling roar. Tidal bores occur in relatively few locations worldwide, typically in areas with a large tidal range of more than 6 meters (20 ft) between high and low water.

How do temperature and salinity differences in ocean water affect ocean currents?

Temperature and salinity differences in ocean water create density variations that drive the vertical movement of ocean currents. Cold-water currents form when dense, cold water sinks and moves from the poles to the equator, while warm-water currents flow from the equator towards the poles, replacing the sinking cold water.

What are gyres and how are they formed?

Gyres are large circular patterns of water movement along the periphery of the ocean basins. They are formed due to the deflection of ocean currents by the Earth's rotation (Coriolis force), as well as the presence of intervening continents and basin topography. Gyres produce a clockwise circulation in the Northern Hemisphere and a counterclockwise circulation in the Southern Hemisphere.

1. What are ocean waves?

Ans. Ocean waves are the disturbances or movements of water that occur on the surface of the ocean. They are typically caused by the wind blowing over the water's surface or by underwater earthquakes, volcanic eruptions, or landslides.

2. How are tides formed?

Ans. Tides are formed due to the gravitational pull of the moon and the sun on the Earth's oceans. The gravitational force causes a bulge in the ocean on the side facing the moon or the sun, creating a high tide. As the Earth rotates, different parts of the ocean experience these bulges, resulting in the rise and fall of tides.

3. What are ocean currents?

Ans. Ocean currents are the continuous, directed movements of ocean water. They can be driven by various factors such as wind, temperature differences, salinity variations, and the Earth's rotation. Ocean currents play a crucial role in regulating climate, distributing heat, nutrients, and marine life, and influencing weather patterns.

4. What are the causes of ocean currents?

Ans. Ocean currents can be caused by several factors. The primary drivers include prevailing winds, which create surface currents, and differences in water density due to variations in temperature and salinity, leading to deep currents. Other factors that contribute to ocean currents include the Coriolis effect, which deflects currents, and the shape of the ocean basins.

5. How do ocean currents influence desert formation?

Ans. Ocean currents play a significant role in influencing desert formation. Warm ocean currents, such as the Gulf Stream, carry moisture from tropical regions to higher latitudes, contributing to the formation of coastal deserts. On the other hand, cold ocean currents, like the California Current, cool the adjacent land, causing dry and arid conditions, which can result in the formation of inland deserts.

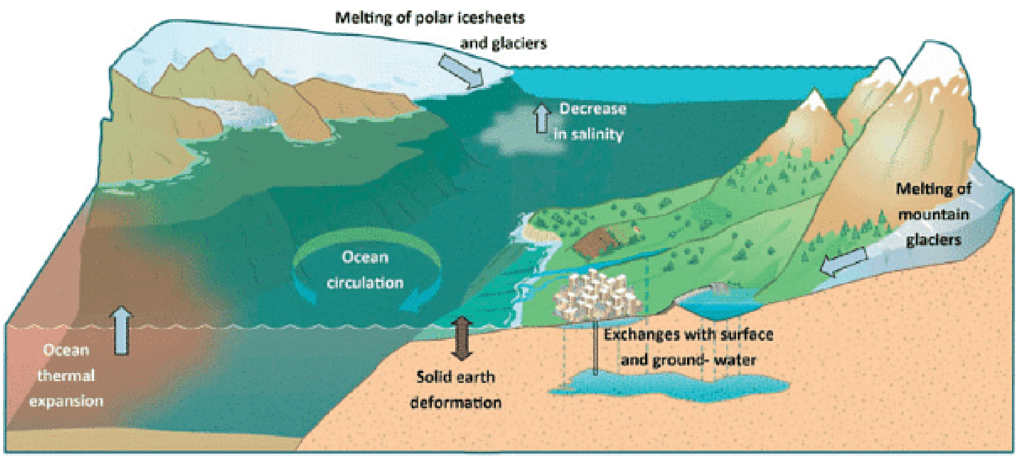
Sea Level Changes

Introduction: Sea Level Changes

- Changes in sea level refer to variations in the average height of the ocean's surface, also known as the mean sea level. These changes can be described as relative changes in sea level.
- A relative rise in sea level can occur when there is an uplift of land or ocean floor, or when both land and ocean floor are experiencing changes in elevation at the same time. In other words, the relative change in sea level is influenced by the shifting of both land and sea surfaces.

What are the two main categories of sea level change?

A. Eustatic and Isostatic **B.** Eustatic and Tectonic **C.** Tectonic and Orogenic **D.** Orogenic and Epeirogenic



The Major Categories of Change in Sea Level are Mentioned Below

The main categories of sea level change can be summarized as follows:

- **Eustatic changes:** These occur when the volume of seawater changes due to factors such as global warming and melting ice sheets, which cause a rise in sea level, or ice ages, which result in a fall in sea level.
- **Tectonic changes:** These involve changes in the land level and can be further divided into three types:
  - **Isostatic changes:** These happen due to the addition or removal of a load on the landmass. For example, during ice ages, the landmass subsided under the immense weight of glacial ice, leading to an apparent rise in sea level. Conversely, the landmass of Scandinavia is still rising as the glacial ice melts and is removed, causing a change in sea level.
  - **Epeirogenic movement:** This occurs when large-scale tilting of continents takes place. As a result, one part of the continent may rise in relation to the mean sea level, while another part may subside, causing an apparent change in sea level.
  - **Orogenic movement:** This is related to the folding and flexing (stretching) of the Earth's crust, which leads to the formation of tall mountains and an apparent decrease in sea level.

In summary, changes in sea level can be attributed to eustatic changes, which involve shifts in the volume of seawater, and tectonic changes, which involve alterations

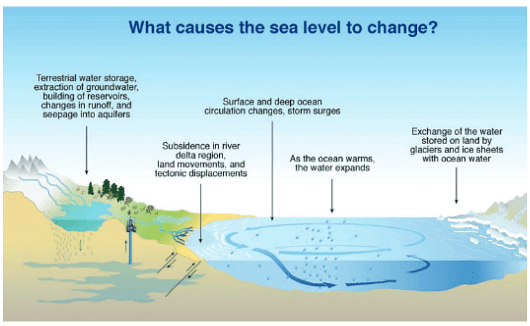
Relevance of the study of sea-level changes

- The study of sea-level changes holds great significance for multiple reasons. Firstly, it offers crucial evidence related to climate change and allows us to establish a reference point for determining the rates of tectonic upliftment in previous geological periods. Sea level changes directly impact the rate and pattern of erosion and deposition processes in coastal regions.

- Understanding sea-level fluctuations is essential for assessing the suitability of coastal areas for industrial development. These fluctuations also dictate the availability of land, particularly in coastal regions, which hold importance for agricultural purposes. The potential submergence of land in the future could have disastrous consequences for human civilization, as it may threaten our food security.
- By predicting climate change and identifying areas that may be submerged undersea, low-lying countries can take proactive steps to construct coastal dykes and embankments. Knowledge of future sea-level rise is also crucial for mapping areas that may be affected by storm surges and periodic flooding.
- Furthermore, the identification of areas that may be submerged in the near future enables us to strategically establish tidal power generation plants in suitable locations. Overall, the study of sea-level changes is essential for informing various aspects of human civilization, from agriculture and industry to energy generation and infrastructure development.

Mechanisms of the Change in Sea-Level

- The fluctuations of sea level involve three basic mechanisms:
  - **changes in ocean water volume;**
  - **changes in ocean basin volume;**
  - **changes in the geoid**, i.e., the shape of the earth changes in the volume of ocean water:
- The present sea level would rise by about 60 to 75 m if the ice in Antarctica melts, whereas the Greenland ice cap would contribute about 5 m rise in sea level.
- It is assumed that, in such a case, the added load of ocean water would lead to the sinking of the ocean floor due to isostatic compensation.
- So the **total rise of sea level would be about 40-50 m. However, the isostatic adjustment of the land and the ocean is still not clear due to a lack of data**.



Changes in the Volume of the Ocean Basin

Variations in the volume of ocean basins and the subsequent changes in sea level were significant events during the Mesozoic Era and the early Cenozoic Era. These changes occur due to several factors, including:

1. **Changes in the volume of mid-ocean ridges:** A key tectonic reason for sea-level rise, mid-ocean ridge volume alterations may occur due to periodic reorganization of plate boundaries, causing fluctuations in the ridge system's total length. When the lithosphere is warm, the spreading rate increases, resulting in an increase in ridge volume and vice versa. As the oceanic ridge volume increases, the sea level rises.
2. **Accumulation of sediments on the ocean floor:** Sediments are generated by the erosion of continents and are deposited on the ocean floor. This deposition can lead to ocean floor subsidence and the removal of sediments either through subduction or upliftment. If these two factors are not considered, the sea level will rise due to the decreased volume of the ocean basin.
3. **Impact of orogenesis:** Orogenesis results in the shortening and thickening of the continental crust and a decrease in the area of continents. Consequently, the sea level falls due to an increase in the volume of the ocean basin.

Short-Term Changes in Global Sea Level

Short-term changes typically occur within a year, with seasonal variations of 5-6 cm in sea level being common. However, sea level fluctuations of 20-30 cm or more are observed in nearly all coastal areas worldwide. Although the causes of such short-term changes are not entirely known, they may be due to a complex interaction of factors such as:

- **Marine water density:** The density of seawater is controlled by temperature and salinity. Low temperature and high salinity result in a higher density of seawater and a lower sea level. This is why the eastern Pacific Ocean has a sea level 30-50 cm higher than the Atlantic Ocean, due to its lower temperature and higher salinity.
- **Atmospheric pressure:** Low pressure results in a higher local sea level and vice versa. In areas of low pressure, the sea level rises locally because water is drawn in by the upward-moving air mass.
- **Velocity of ocean currents:** Fast-flowing ocean currents cause a sea-level rise on their outer fringes when taking a curved path.

- **Ice formation and fall in sea level:** During winter, ocean water trapped in the ice caps of the northern and southern hemispheres leads to a decrease in sea level.
- **Piling up of water along windward coasts:** A local rise in sea level occurs in coastal regions when water is driven towards the coasts by an air mass, such as during the monsoon months in South and East Asia.
- Additionally, the twentieth century has observed short-term global sea-level rise due to factors such as global warming caused by human activities, resulting in the thermal expansion of ocean water.

The effects of a sea-level fall include changes in the base level of rivers, rejuvenation of landforms, shoreline extension, river lengthening, coral reef death, and ice cap expansion.

Which factor contributes to short-term changes in global sea level? A. Changes in the volume of mid-ocean ridges **B.** Accumulation of sediments on the ocean floor **C.** Impact of orogenesis **D.** Marine water density

Conclusion

Sea level changes are a crucial aspect of Earth's natural processes and are influenced by eustatic and tectonic factors. Understanding these changes is essential for addressing the impacts of climate change, managing coastal development, and informing various sectors of human civilization. The study of sea level changes involves analyzing mechanisms such as ocean water volume, ocean basin volume, and geoid changes. Short-term fluctuations in sea level are also significant and can result from various factors, including marine water density, atmospheric pressure, and ocean currents. As we continue to face the consequences of climate change and human activities, monitoring and understanding sea level changes becomes increasingly important for the sustainable development and adaptation of our societies.

What are the main factors causing changes in sea level?

The main factors causing changes in sea level are eustatic changes, which involve shifts in the volume of seawater, and tectonic changes, which involve alterations in the land level. Eustatic changes occur due to factors like global warming, melting ice sheets, and ice ages, while tectonic changes involve isostatic changes, epeirogenic movement, and orogenic movement.

Why is the study of sea-level changes important?

The study of sea-level changes is important because it offers evidence related to climate change, helps determine rates of tectonic upliftment, impacts erosion and deposition processes, informs the suitability of coastal areas for development, and enables the identification of areas that may be submerged in the future. It also aids in planning for coastal protection measures, storm surge predictions, and tidal power generation.

What are the short-term changes in global sea level?

Short-term changes in global sea level typically occur within a year and can be attributed to factors such as marine water density, atmospheric pressure, velocity of ocean currents, ice formation, and piling up of water along windward coasts. Additionally, human-induced global warming has caused sea-level rise due to the thermal expansion of ocean water.

1. What causes sea level changes?

Ans. Sea level changes are primarily caused by two factors: the melting of land-based ice (such as glaciers and ice sheets) and the thermal expansion of seawater. As global temperatures increase, ice on land melts and flows into the ocean, contributing to higher sea levels. Additionally, as seawater warms, it expands and takes up more space, leading to a rise in sea levels.

2. How do changes in the volume of the ocean basin affect sea levels?

Ans. Changes in the volume of the ocean basin can affect sea levels in different ways. For instance, if the volume of the ocean basin increases, it can cause the water to spread out and result in a rise in sea levels. Conversely, if the volume of the ocean basin decreases, the water may become more confined, leading to a drop in sea levels. These changes in the volume of the ocean basin can occur due to tectonic movements, such as the uplift or subsidence of land, or the deposition or erosion of sediment.

3. How do sea level changes impact coastal areas?

Ans. Sea level changes can have significant impacts on coastal areas. Rising sea levels can result in coastal erosion, increased coastal flooding, and saltwater intrusion into freshwater sources. Coastal communities may experience loss of land, damage to infrastructure, and displacement of populations. Moreover, increased storm surges and higher tides can exacerbate the effects of sea level rise, leading to more frequent and severe coastal hazards.

4. Are sea level changes uniform across the globe?

Ans. No, sea level changes are not uniform across the globe. While the average global sea level has been rising, the rate of sea level rise can vary regionally. Different factors, such as ocean currents, wind patterns, and gravitational forces, can cause variations in sea level changes. Some areas may experience higher rates of sea level rise, while others may see relatively lower or even falling sea levels due to local factors and geological processes.

5. How can we measure and monitor sea level changes?

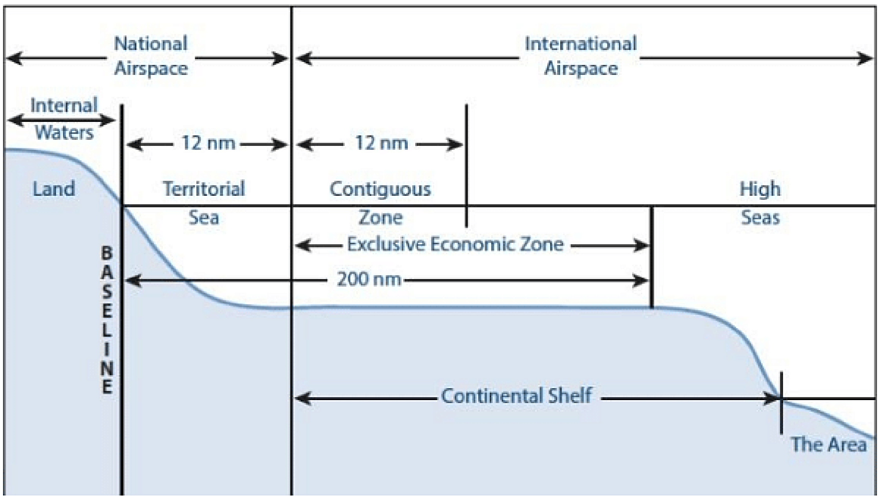
Ans. Scientists use various methods to measure and monitor sea level changes. One common technique is through tide gauges, which are instruments that measure the height of the ocean surface relative to a reference point on land. Satellite altimetry is another important tool, where satellites measure the distance between the satellite and the ocean surface to determine sea level changes. Additionally, data from GPS stations, ocean buoys, and underwater sensors are used to gather information on sea level variations. These measurements are crucial for understanding the extent and impacts of sea level changes and for informing coastal planning and adaptation strategies.

Law of the Sea & Marine Pollution

UNCLOS

- The United Nations Convention on the Law of the Sea (UNCLOS), also known as the Law of the Sea Convention or the Law of the Sea Treaty, is an international agreement that provides a legal framework for all activities related to marine and maritime affairs. As of June 2016, 167 countries and the European Union are parties to the agreement.
- UNCLOS resulted from the third United Nations Conference on the Law of the Sea (UNCLOS III), which took place between 1973 and 1982, and was adopted and signed in 1982. The convention replaced the four Geneva Conventions of April 1958, which dealt with various aspects of maritime law.
- The Convention established three new international institutions: the International Tribunal for the Law of the Sea, the International Seabed Authority, and the Commission on the Limits of the Continental Shelf. It also divided marine areas into five main zones: Internal Waters, Territorial Sea, Contiguous Zone, Exclusive Economic Zone (EEZ), and the High Seas.
- UNCLOS is the only international convention that provides a framework for state jurisdiction in maritime spaces, with different legal statuses for each maritime zone. It serves as the foundation for offshore governance by coastal states and those navigating the oceans, zoning coastal states' offshore areas and providing specific guidance for states' rights and responsibilities in the five concentric zones.

Maritime Zones



1. Baseline

- It is the **low-water line along the coast as officially recognized by the coastal state**.

2. Internal Waters

- Internal waters refer to the water areas located on the landward side of the baseline that is used to measure the breadth of a coastal state's territorial sea. These waters fall under the complete sovereignty of the coastal state, similar to its land territory. Examples of internal waters include bays, ports, inlets, rivers, and lakes that have a connection to the sea.
- Unlike territorial waters, there is no right of innocent passage through internal waters. Innocent passage refers to the right to travel through waters without posing any threat to the peace and security of the nation. However, it is important to note that coastal states reserve the right to suspend innocent passage rights if deemed necessary.

3. Territorial Sea

- The territorial sea refers to the area extending up to 12 nautical miles (nm) from a country's coastline, measured from its baselines. A nautical mile, which is slightly more than a land mile (1 nautical mile = 1.1508 land miles or 1.85 km), is based on the Earth's circumference and is equivalent to one minute of latitude.
- Coastal states possess sovereignty and jurisdiction over the territorial sea, which includes not only the water's surface but also the seabed, subsoil, and airspace above. However, these rights are subject to the principle of innocent passage, which allows for the unobstructed passage of ships through the territorial sea as long as it does not compromise the coastal state's security or interests.

4. Contiguous Zone

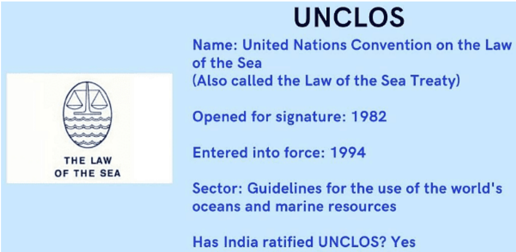
- The contiguous zone is a maritime area that stretches up to 24 nautical miles (nm) from a country's baselines, acting as a buffer between the territorial sea and the high seas. This zone allows the coastal state to exercise control over its surface and seabed, but not over the air and space above it.
- In this area, the coastal state has the authority to prevent and penalize violations of fiscal, immigration, sanitary, and customs laws within its territory and territorial sea. However, the contiguous zone's jurisdiction is limited to the ocean's surface and floor, without extending to airspace or outer space.

5. Exclusive Economic Zone (EEZ)

- An Exclusive Economic Zone (EEZ) is a maritime area that extends up to 200 nautical miles from a coastal state's baseline, beyond its territorial sea. Within this zone, the coastal state has specific rights and jurisdiction related to the exploration, exploitation, conservation, and management of both living and nonliving natural resources found in the seabed and subsoil. Additionally, the coastal state can conduct activities such as harnessing energy from water, currents, and wind.
- It is important to note that the EEZ differs from the territorial sea and the contiguous zone in that it primarily concerns resource rights. The coastal state does not have the authority to restrict or regulate freedom of navigation or overflight within its EEZ, except for a few limited exceptions.

6. High Seas

- The high seas refer to the ocean surface and the water column beyond the Exclusive Economic Zone (EEZ), which is an area beyond any national jurisdiction.
- This region is considered as the shared inheritance of all humanity, and states can engage in activities within these waters as long as they serve peaceful purposes. Examples of such activities include transit, marine scientific research, and undersea exploration.



- Oceans are the largest water bodies on the planet Earth. Over the last few decades, excessive human activities have severely affected marine life on the Earth's oceans. **Ocean pollution, also known as marine pollution, is the spreading of harmful substances such as oil, plastic, industrial and agricultural waste, and chemical particles into the ocean**.
- Since oceans provide the home to a wide variety of marine animals and plants, it is the responsibility of every citizen to play his or her part in making these oceans clean so that marine species can thrive for a longer period of time.

7. Laws and Policies

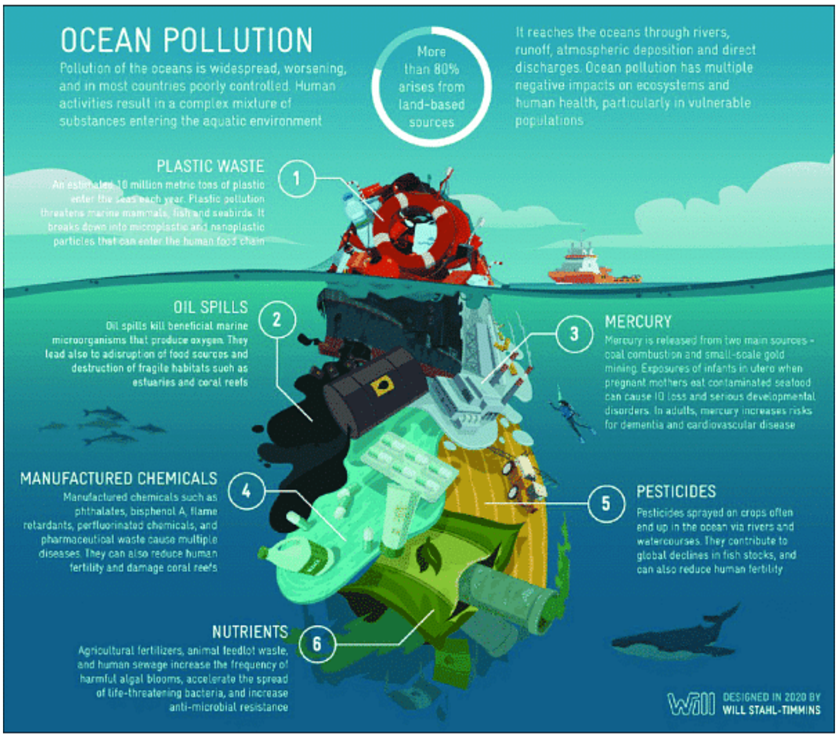
- In 1948, President Harry Truman signed a law known as the Federal Water Pollution Control Act, which granted the federal government the authority to regulate marine pollution in the United States.
- In 1972, the Council on Environmental Quality passed the Marine Protection, Research, and Sanctuaries Act, which aimed to control the dumping of waste into the ocean.
- Furthermore, the international treaty MARPOL was created in 1973 and revised in 1978 to address pollution from ships, with a particular focus on oil pollution. The International Convention for the Prevention of Pollution from Ships in 1983 further enforced the MARPOL treaty on a global scale.
- Additionally, the United Nations Convention on the Law of the Sea (UNCLOS) was established in 1982 to protect the marine environment by requiring all participating countries to regulate their pollution levels in the ocean. This convention imposed restrictions on the amount of toxins and pollutants that ships from all countries could release into the ocean.

Which of the following is NOT a maritime zone according to the United Nations Convention on the Law of the Sea (UNCLOS)? A. Internal Waters **B.** Territorial Sea **C.** Exclusive Economic Zone (EEZ) **D.** Coastal Buffer Zone

Causes of Ocean Pollution

1. **Plastic Waste:** Between 4-12 million metric tons of plastic waste enters the ocean each year. India alone generates 62 million metric tons of waste annually, with 10-12% of this being plastic waste, including single-use plastics.
2. **Sewage:** Pollution can directly enter the ocean through sewage systems, rivers, or drainage channels. In India, 80% of municipal sewage is collected, but only 20% is treated, with the remaining untreated sewage being directly discharged into the ocean.
3. **Industrial and Agricultural Waste:** Toxic chemicals from industrial and agricultural processes are another common source of ocean pollution. The disposal of harmful liquids in the ocean has a direct impact on marine life.
4. **Land Runoff:** Land runoff occurs when excess water from rain, flooding, or melting infiltrates the soil and flows over land into the ocean. This process often picks up harmful human-made contaminants, such as fertilizers, petroleum, pesticides, and other soil pollutants. Around 80% of land discharge that enters the sea contains plastic waste.
5. **Large Scale Oil Spills:** Ship pollution, particularly oil spills, is a significant source of ocean pollution. Crude oil is highly toxic to marine life and can suffocate animals once they become trapped in it. Furthermore, crude oil is challenging to clean up and tends to persist in the ocean for years.
6. **Deep-Sea Mining:** Ocean mining in the deep sea also contributes to ocean pollution. Mining sites that drill for silver, gold, copper, cobalt, and zinc create sulphide deposits up to 3,500 meters deep in the ocean.
7. **Littering:** Atmospheric pollution is a surprisingly large contributor to ocean pollution. Objects, both natural (e.g., dust and sand) and man-made (e.g., debris and trash), can be carried by the wind over long distances and eventually end up in the ocean. Most debris, particularly

plastic debris, does not decompose and remains suspended in ocean currents for extended periods.



Devastating Effects of Ocean Pollution

- **Effect of Toxic Wastes on Marine Animals:** The oil spill is dangerous to marine life in several ways. The oil spilled in the ocean could get onto the gills and feathers of marine animals, which makes it difficult for them to move or fly properly or feed their children. The long-term effect on marine life can include cancer, failure in the reproductive system, behavioral changes, and even death.
- **Disruption to the Cycle of Coral Reefs:**
    - Oil spill floats on the surface of the water and prevents sunlight from reaching to marine plants and affects the process of photosynthesis. Skin irritation, eye irritation, lung and liver problems can impact marine life over a long period of time.
      (i) Depletes Oxygen Content in Water
      (ii) Failure in the Reproductive System of Sea Animals
      (iii) Effect on Food Chain
    - Chemicals used in industries and agriculture get washed into the rivers and from there are carried into the oceans. These chemicals do not get dissolved and sink at the bottom of the ocean. Small animals ingest these chemicals and are later eaten by large animals, which then affect the whole food chain.
- **Eutrophication:** When a water body becomes overly enriched with minerals and nutrients which induce excessive growth of algae or **algal bloom**.
    - This process also results in oxygen depletion of the water body.
- **Affects Human Health:** Animals from the impacted food chain are then eaten by humans which affects their health as toxins from these contaminated animals get deposited in the tissues of people and can lead to cancer, birth defects or long-term health problems.

Solutions for Ocean Pollution

- A **stricter government regulation on industry and manufacturing** is one large scale solution.
- **Implement renewable energy sources**, such as wind or solar power, to limit offshore drilling.
- **Limit agricultural pesticides and encourage organic farming and eco-friendly pesticide use**.
- **Proper sewage treatment** and exploration of eco-friendly wastewater treatment options.
- **Cut down on industry and manufacturing waste** and contain landfills so they don't spill into the ocean.

Oceans are resilient, but not indestructible. If they're to last for generations to come, humans must work together to reduce pollution and its impact. **The best way to fight ocean pollution is to educate yourself on its causes and make**

small changes at home to reduce your carbon footprint. It's never too late to work to improve the ocean's health.
Oceans Issues and Threats – Currently our **Oceans** are facing the following major problems:

- Over Fishing
- Predation of Top predators
- Ocean Acidification
- Coral Bleaching
- Ocean Dead Zone
- Heavy metal Pollution
- Plastic Pollution

Over Fishing

- Overfishing is causing significant damage to our oceans and their ecosystems. This practice not only threatens the extinction of various fish species but also affects other marine animals that rely on these fish for sustenance. Overfishing results in food scarcity for marine animals, as humans deplete their food sources at a faster rate than they can replenish. In fact, many seas already require long-term fishing bans for certain species to have any chance of recovery.
- Moreover, the fishing methods employed contribute to the destruction of ocean habitats. For example, bottom trawling devastates seafloor habitats and often captures numerous unwanted fish and marine animals, which are then discarded. Additionally, the over-extraction of fish has led to many species being classified as threatened or endangered.
- The primary cause of overfishing is the increased demand for seafood. As people seek to diversify their diets and capitalize on the health benefits of seafood, the pressure on fish populations continues to grow. To mitigate the harmful effects of overfishing, it is crucial to implement sustainable fishing practices and reduce our reliance on seafood.

Predation of Top predators

- Each year, tens of millions of sharks are killed, predominantly for their fins, which are used as an ingredient in soup. The common practice involves capturing the sharks, cutting off their fins, and then throwing them back into the ocean to die, resulting in a tremendous amount of waste.
- As apex predators, sharks have slow reproduction rates, making it difficult for their populations to recover from overfishing. Additionally, their role as top predators helps regulate the population of other species. When a key predator is removed from the ecosystem, species lower on the food chain often begin to overpopulate their habitat, leading to a detrimental cascading effect on the entire ecosystem.
- Whaling is another significant issue that has pushed the blue whale population to the brink of collapse.

Ocean Acidification

- Ocean acidification is a significant problem that cannot be ignored. It occurs when the ocean absorbs CO_2 through natural processes. However, due to the increased levels of CO_2 being released into the atmosphere from burning fossil fuels, the ocean's pH balance is dropping at an alarming rate, making it difficult for marine life to adapt.
- According to Jelle Bijma, chair of the EuroCLIMATE program Scientific Committee and a biogeochemist at the Alfred Wegener-Institute Bremerhaven, "Ocean acidification is occurring more rapidly than ever in Earth's history. To find equivalent levels of pCO_2 (partial pressure of carbon dioxide) that we have reached now, one needs to go back 35 million years in time."
- It's crucial to note that the average pH of ocean water is basic, at around 8.1. Ocean acidification causes the pH level to decrease slightly, but it does not fall below 7. If the pH were to drop below 7, it would become acidic, and no marine life would be able to survive in such conditions.

Coral Bleaching

Understanding Coral Reefs
Coral reefs are underwater structures composed of coral polyps, which are tiny living organisms. These coral polyps create calcium carbonate skeletons that bind together to form the reef. Even though coral reefs only cover 0.1% of the ocean's surface, they are home to 25% of marine species, earning them the nickname "tropical rainforests of the sea." Coral reefs are typically found in shallow areas with depths less than 150 feet, but some can reach depths of up to 450 feet. While corals can be found in all oceans, the largest coral reefs are usually located in the clear, shallow waters of tropical and subtropical regions.
Ideal Growth Conditions for Coral Reefs

- **Temperature:** Coral reefs thrive in water temperatures between 20°C and 35°C, with the optimal range being 23°C to 25°C. Water temperatures below 20°C are not conducive to coral growth.

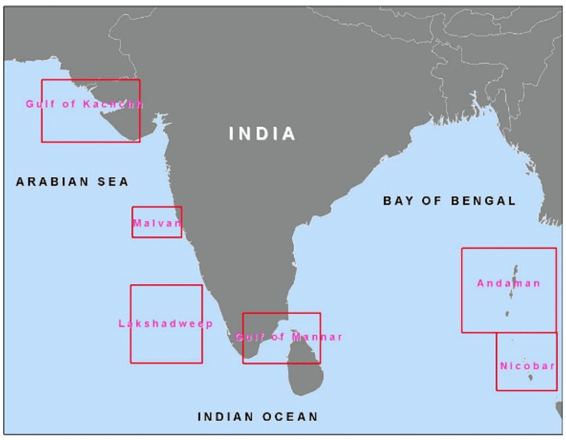
- **Salinity:** Corals can only survive in saline conditions, with an average salinity level between 27% and 40%.
- **Water Depth:** Coral reefs grow best in shallow waters with depths of less than 50 meters. However, they can still be found in waters with depths up to 200 meters.

Types of Coral Reefs

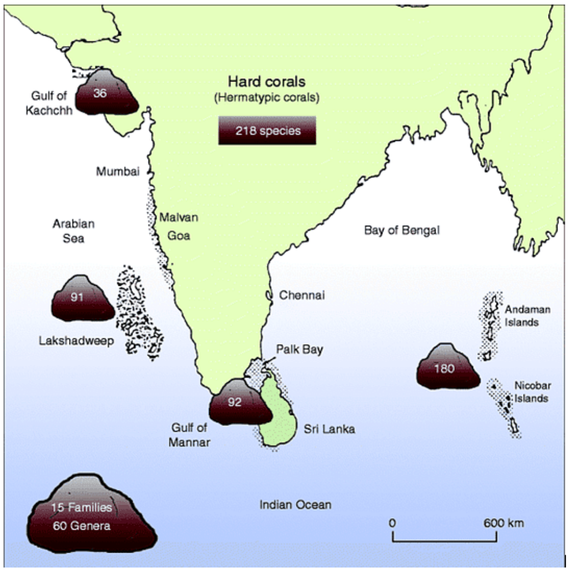
Coral Reefs are differentiated into three categories based on their shape, nature, and mode of occurrence.

- **Fringing Reef:** Fringing coral reefs are located very close to the shore, forming a shallow lagoon known as a Boat Channel. These reefs grow alongside islands and continental margins, developing from the deep sea floor and featuring a steep seaward slope. Fringing reefs are the most common type of coral reef. Examples include Sakau Island in New Hebrides and the South Florida Reef.
- **Barrier Reef:** Among the three types of coral reefs, barrier reefs are the largest, tallest, and widest. They form off the coast and run parallel to the shore in a broken and irregular ring shape. Barrier reefs can span over 100 kilometers in length and several kilometers in width. The Great Barrier Reef in Australia, which stretches for 1,200 miles, is an example of a barrier reef.
- **Atolls:** An atoll is a coral reef that has a roughly circular shape and encircles a large central lagoon, which is typically deep with depths ranging from 80 to 150 meters. Atolls are found away from deep sea platforms and can be situated around an island or on a submarine platform in an elliptical form. Examples of atolls include the Fiji Atolls, Suvadivo in the Maldives, and Funafoothis Atoll of Ellice.

Coral Reefs in India



The major coral reefs in India include **Palk Bay**, **the Gulf of Mannar, the Gulf of Kutch, the Andaman and Nicobar Islands, the Lakshadweep Islands, and Malvan**. Among all these coral reefs, the **Lakshadweep reef is an example of an atoll** while the **rest are all fringing reefs**.



Coral Bleaching

- Coral bleaching occurs when corals, under stress from changes in factors such as temperature, light, or nutrient levels, expel the symbiotic algae called zooxanthellae that live within their tissues. These algae provide about 90% of the coral's energy and give the coral its yellow or reddish-brown color. When the algae are expelled, the coral turns a pale white, revealing its translucent calcium carbonate tissues.
- The loss of zooxanthellae pigment makes the coral appear "bleached," but it does not necessarily result in the coral's death. If the bleaching is not too severe, corals can recover once conditions return to normal. Coral bleaching has been observed in the Caribbean, Indian, and Pacific oceans on a recurring basis. While bleaching brings corals close to death, some can survive and recuperate when the sea surface temperature stabilizes.

Causes of Coral Bleaching?

1. **Rising sea temperatures:** Most coral species live in waters close to their maximum heat tolerance, making even a slight increase in ocean temperature harmful to them. Events like El Niño can raise sea temperatures and damage coral reefs.
2. **Ocean acidification:** As carbon dioxide levels rise, oceans absorb more of the gas, increasing the acidity of the water. This makes it more difficult for corals to create their essential calcareous skeletons.
3. **Solar radiation and ultraviolet radiation:** Changes in tropical weather patterns can lead to reduced cloud

cover, exposing coral to more radiation and consequently causing bleaching.

4. **Infectious diseases:** Bacteria such as Vibrio shiloi can infiltrate coral and inhibit the photosynthesis of zooxanthellae, the algae living within coral. These bacteria become more harmful in warmer sea temperatures.
5. **Chemical pollution:** Higher nutrient concentrations can negatively impact corals by promoting phytoplankton growth, which in turn supports larger populations of organisms that compete with coral for space.
6. **Increased sedimentation:** Land clearing and coastal construction can cause higher rates of erosion, leading to more suspended silt particles in the water. This can smother corals, reduce light availability, and hinder coral photosynthesis and growth.
7. **Human-induced threats:** Overfishing, pollution from agricultural and industrial runoff, coral mining, and the development of industrial areas near coral ecosystems can also adversely affect corals.

Consequences

- The consequences of coral bleaching are significant and far-reaching, impacting both the marine ecosystem and human communities. When coral communities change, the species that rely on them, such as fish and invertebrates, are affected. These marine animals depend on living coral for food and shelter, and their loss can disrupt the entire food chain, leading to declines in genetic and species diversity.
- Not only do healthy coral reefs support a diverse range of marine life, but they also attract divers and tourists, providing a boost to the local economy. However, when coral reefs are bleached and degraded, it can deter tourism and negatively affect the financial well-being of the surrounding communities.
- Coral bleaching can also lead to significant shifts in fish populations, resulting in reduced catches for fishermen. This not only impacts the food supply for local communities but also affects the economic activities associated with fishing.
- Additionally, coral reefs play a crucial role in protecting coastlines by absorbing wave energy from the ocean. This helps to shield coastal populations from increased storm damage, erosion, and flooding. As coral bleaching compromises the health and structure of coral reefs, this vital protective function is weakened, leaving coastal communities more vulnerable to the elements.

Ocean Dead Zone

- Ocean dead zones are areas in the ocean where life cannot thrive due to a lack of oxygen. It is believed that global warming plays a significant role in causing these dead zones, which are increasing at an alarming rate. Currently, more than 400 dead zones have been identified, and this number is expected to rise.
- Research on dead zones highlights the interdependence of our planet's ecosystems. It suggests that promoting biodiversity in land-based agriculture could help prevent the formation of dead zones in the ocean. This could be achieved by reducing or eliminating the use of fertilizers and pesticides, which can eventually make their way into the ocean and contribute to the development of dead zones.

Heavy Metal Pollution

- Heavy metal pollution, particularly mercury, is a significant concern in ocean waters, as it poses a threat to marine life and eventually finds its way onto our dinner plates. The issue of mercury pollution is becoming increasingly severe, with most coastal nations now grappling with the impacts of mercury poisoning.
- The long-lasting nature of mercury enables it to bioaccumulate and magnify in the food chain. The primary source of mercury in water is coal-based thermal power plants, which release the pollutant into the environment. To address this problem, countries have come together under the Minamata Convention to work towards reducing the use and production of mercury.

Plastic Pollution

- Vast amounts of plastic debris are accumulating in the ocean, forming a massive "plastic soup" roughly the size of Texas in the center of the Pacific Ocean. This plastic pollution is causing significant harm to marine life, particularly large fish, which often choke on the plastic materials.
- When fish ingest plastic bags, these items can become lodged in their digestive tracts, leaving no room for food and ultimately leading to death by starvation. Much of this plastic waste enters the ocean through drains and rivers, continuously adding to the growing problem.

Great Barrier Reef

The Great Barrier Reef is the world’s largest coral reef system composed of over 2,900 individual reefs and 900 islands stretching for over 2,300 kilometres over an area of

approximately 344,400 square kilometres. The reef is located in the Coral Sea, off the coast of Queensland, Australia.

The Great Barrier Reef, the largest single structure on Earth created by living organisms, is visible from outer space. This remarkable structure is made up of billions of tiny coral polyps, which together support an incredibly diverse range of life. In recognition of its significance, the Great Barrier Reef was designated as a World Heritage Site in 1981.

The Great Barrier Reef Marine Park, which is approximately the same size as Italy, encompasses around 3,000 individual coral reefs, 600 continental islands, and is home to an astonishing 1,625 species of fish, 133 types of sharks and rays, and 600 varieties of both soft and hard corals.

What is the primary cause of coral bleaching? A. Rising sea temperatures **B.** Increased sedimentation **C.** Human-induced threats **D.** Infectious diseases

Conclusion

The health of our oceans is critically important for the survival and well-being of both marine ecosystems and human communities. Challenges such as overfishing, ocean acidification, coral bleaching, ocean dead zones, heavy metal pollution, and plastic pollution pose significant threats to the marine environment. It is essential for nations and individuals to take collective action, implement sustainable practices, and enforce stricter regulations to protect and preserve the oceans for future generations.

What is the United Nations Convention on the Law of the Sea (UNCLOS)?

The United Nations Convention on the Law of the Sea (UNCLOS) is an international agreement that provides a legal framework for all activities related to marine and maritime affairs. It establishes the rights and responsibilities of nations in their use of the world's oceans, dividing marine areas into various zones with different legal statuses.

What are the main types of coral reefs, and where are they commonly found?

There are three main types of coral reefs: fringing reefs, barrier reefs, and atolls. Fringing reefs are located close to the shore and are the most common type of coral reef. Barrier reefs are the largest, tallest, and widest reefs, forming off the coast and running parallel to the shore. Atolls are circular reefs that encircle a large central lagoon. Coral reefs are typically found in shallow, clear waters of tropical and subtropical regions.

What is coral bleaching, and what causes it?

Coral bleaching occurs when corals, under stress from changes in factors such as temperature, light, or nutrient levels, expel the

symbiotic algae called zooxanthellae that live within their tissues. This causes the coral to turn a pale white and lose its vibrant color. The primary cause of coral bleaching is rising sea temperatures, but other factors such as ocean acidification, solar radiation, infectious diseases, and human-induced threats can also contribute to the problem.

What are ocean dead zones, and what causes them?

Ocean dead zones are areas in the ocean where life cannot thrive due to a lack of oxygen. The main cause of dead zones is nutrient pollution from human activities, such as fertilizer and sewage runoff, which promotes excessive algal growth. When the algae die and decompose, they consume the oxygen in the water, creating an environment that is inhospitable for most marine life.

How can we reduce ocean pollution and protect marine ecosystems?

Some solutions for reducing ocean pollution include implementing stricter government regulations on industry and manufacturing, promoting renewable energy sources, limiting agricultural pesticide use, improving sewage treatment, reducing plastic waste, and raising awareness about sustainable fishing practices. By making small changes at home and supporting policies that protect marine ecosystems, individuals can help improve the health of the oceans.

1. What is UNCLOS?

Ans. UNCLOS stands for the United Nations Convention on the Law of the Sea. It is an international treaty that establishes the legal framework for the use and conservation of the world's oceans and their resources. UNCLOS defines the rights and responsibilities of nations in relation to the oceans, including territorial waters, exclusive economic zones, and the high seas.

2. What are the causes of ocean pollution?

Ans. Ocean pollution can be caused by various factors, including: - Industrial and domestic waste: Discharge of untreated or poorly treated sewage, chemicals, and other waste products into the oceans. - Oil spills: Accidental or deliberate release of oil from ships, offshore drilling rigs, or other sources. - Marine debris: Plastics, fishing nets, and other solid waste that end up in the ocean, often causing harm to marine life. - Agricultural runoff: Excessive use of fertilizers and pesticides that wash into rivers and eventually reach the oceans, leading to eutrophication and harmful algal blooms. - Atmospheric pollution: Airborne pollutants, such as mercury emissions from coal-fired power plants, can settle on the ocean surface and contaminate marine life.

3. What is coral bleaching?

Ans. Coral bleaching is a phenomenon where corals lose their vibrant colors and turn white or pale due to stress. It occurs when corals are exposed to high water temperatures, pollution, or other environmental factors. When corals are stressed, they expel the symbiotic algae called zooxanthellae, which provide them with nutrients and give them their colorful appearance. Without these algae, the corals become more susceptible to disease and can eventually die.

4. What are the impacts of coral bleaching?

Ans. Coral bleaching has several negative impacts on coral reefs and marine ecosystems. Some of the impacts include: - Loss of biodiversity: Coral reefs are among the most diverse ecosystems on the planet, and coral bleaching can lead to the loss of numerous species that depend on these reefs for shelter and food. - Economic losses: Coral reefs support tourism, fishing, and other industries, and their degradation due to bleaching can result in significant economic losses for coastal communities. - Breakdown of the food chain: Coral reefs serve as nurseries and feeding grounds for various marine organisms. When corals die, it disrupts the entire food chain and affects the abundance and distribution of fish and other marine species. - Coastal protection: Healthy coral reefs provide natural barriers against storms and waves, helping to protect coastal areas from erosion and flooding. Bleached and dying corals are less effective in providing this vital coastal protection.

5. How does UNCLOS address marine pollution?

Ans. UNCLOS includes provisions to address marine pollution and promote the protection and preservation of the marine environment. It establishes the general obligation of states to prevent, reduce, and control pollution of the marine environment from any source. UNCLOS also emphasizes the need for cooperation among states to develop and implement international rules and standards to prevent and combat marine pollution. Additionally, it provides a framework for states to take measures such as establishing marine protected areas and regulating activities that may have harmful impacts on the marine environment.

Coral Reefs & Coral Bleaching

Introduction

- Corals are essentially calcified structures created by the skeletons of tiny marine creatures known as polyps. These polyps extract calcium salts from the surrounding seawater and use them to form rigid skeletons, which serve as a protective barrier for their soft bodies. The resulting structures are what we commonly refer to as corals.
- These corals exist in colonies that are attached to the rocky ocean floor. As new generations of polyps develop, they build their skeletons on top of the remains of deceased polyps. Over time, the tubular skeletons grow both upwards and outwards, creating a solid, calcareous rock mass known collectively as corals.
- The formation of a shallow rock layer due to these accumulations is known as a reef. Over time, these reefs can develop into islands. Corals can be found in various shapes and colors, which is dependent on the type of salts or other components that make up their composition.
- The continued growth of corals can result in them appearing in various forms on the ocean's surface over an extended period. Additionally, small marine plants called algae also contribute to coral growth by depositing calcium carbonate.

Ideal Conditions for Coral Growth

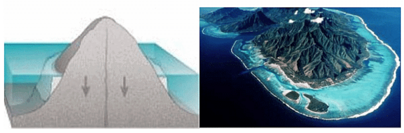
- Coral growth is best suited for tropical regions, specifically between 30°N and 30°S latitudes. The optimal depth for corals to thrive is between 45 and 55 meters below the sea surface, as this depth provides ample sunlight exposure.
- Water temperatures around 20°C are ideal for coral growth. Clear saltwater is necessary for corals to prosper, while both freshwater and highly saline water can be detrimental to the growth of coral polyps.
- A sufficient supply of oxygen and microscopic marine food, known as plankton, is crucial for the growth and survival of corals. Since there is a higher abundance of food on the seaward side, corals tend to grow more rapidly in that area.

What are the three main types of coral reefs? A. Fringing reefs, lagoon reefs, and island reefs **B.** Fringing reefs, barrier reefs, and atolls **C.** Barrier reefs, island reefs, and lagoon reefs **D.** Fringing reefs, island reefs, and seamount reefs

Types of Coral Reefs

Coral reefs can be categorized based on their large-scale morphology, which includes their size, shape, and relationship to nearby landmasses. Although there can be some overlap among the different types of reefs, they are generally distinguishable from one another. The three main types of coral reefs are fringing reefs, barrier reefs, and atolls.

- In the context of coral reef classification, a **lagoon** refers to a relatively wide body of water situated between the shore and the main reef area. This body of water usually contains some deeper sections.
- **Fringing reefs** are the most common of the three major types of coral reefs. These reefs are coral platforms that are attached to a continental coast or an island, and they are sometimes separated from the shore by a narrow, shallow lagoon or channel. Fringing reefs typically extend as a narrow belt, ranging from 0.5 km to 2.5 km in width. They grow from the deep ocean floor, with their seaward side sloping steeply into the deep sea. Coral polyps do not extend outward due to the sudden and significant increase in depth. The surface of a fringing reef is typically rough, as it is covered with coral remains, forming a boulder zone or reef flat.

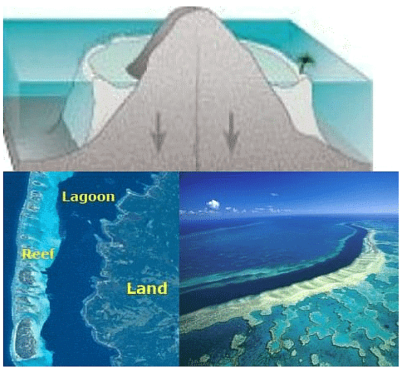


Barrier Reef

- A barrier reef is the largest among the three types of coral reefs and spans hundreds of kilometers in length and several kilometers in width. It forms an irregular, discontinuous ring around a coastline or an island, situated almost parallel to the shore. One of the

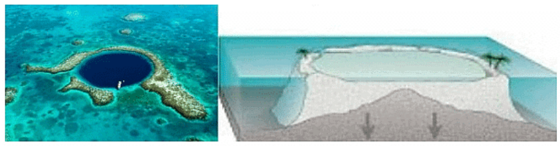
distinguishing features of a barrier reef is its relatively far location from the coast, accompanied by a wider and deeper lagoon. Occasionally, channels that cut across the barrier reef connect the lagoon to the open sea.

- In terms of structure, a barrier reef is quite thick, reaching depths of up to 180 meters below the surface. The seaward side of the reef exhibits a steep slope that descends into the deep ocean. The surface of barrier reefs typically consists of coral debris, boulders, and sand.
- The most well-known example of a barrier reef is the Great Barrier Reef, located off the northeastern coast of Australia. This massive reef stretches over 1,900 kilometers in length and spans up to 160 kilometers in width.



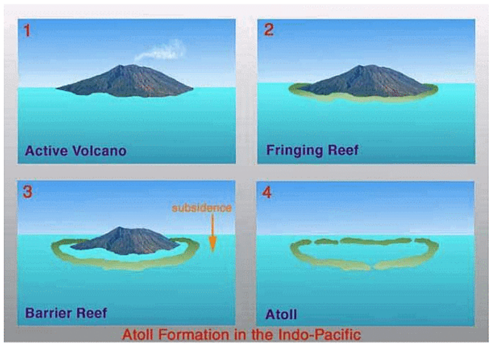
Atolls

- Atolls are ring-shaped coral reefs that either partially or entirely encircle a lagoon. The lagoon's surface is typically level, while the seaward side of the reef has a steep slope that descends into the deep sea. Lagoons can have depths ranging from 80 to 150 meters and may connect with the sea through channels that cut across the reef.
- Atolls are often formed in areas far from deep-sea platforms, where underwater features like submerged islands or volcanic cones provide suitable conditions for coral growth. They are more commonly found in the Pacific Ocean than any other ocean, with notable examples including the Fiji atoll and the Funafuti atoll in the Ellice Islands. The Lakshadweep islands also host a significant number of atolls.
- In the South Pacific, many atolls are located in the middle of the ocean. These reef formations can be found in places like French Polynesia, the Caroline and Marshall Islands, Micronesia, and the Cook Islands. The Indian Ocean also contains a substantial amount of atolls, with examples in the Maldives and Chagos island groups, the Seychelles, and the Cocos Island group.



Formation of Lakshadweep Islands (Atoll Formation)

- The classification system for coral reefs, initially proposed by Charles Darwin, continues to be widely used today. According to Darwin's theory, fringing reefs start to develop near the coastlines of newly formed islands when ecological conditions become favorable for the growth of hard corals.
- As the island slowly sinks into the sea, the coral continues to grow at a rate that allows it to stay at the sea surface but moves further away from the shore, turning into a barrier reef. Eventually, the island submerges completely beneath the sea, leaving behind a ring of coral that encircles a central lagoon, thus forming an atoll.



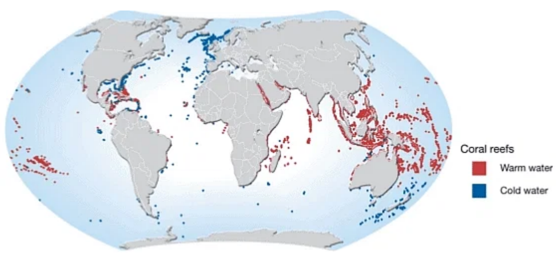
Atoll Formation in the Indo-Pacific

Distribution of Coral Reefs

The majority of reef-building corals can be found in tropical and subtropical waters, usually between 30° north and 30° south latitudes. The area with the highest concentration of coral reefs and the most diverse coral species is the Indonesian and Philippine archipelago. Other significant regions with coral reef concentrations include Australia's Great Barrier Reef, the Red Sea, and the Caribbean, although the Caribbean has a much lower diversity compared to the major Indo-Pacific regions.

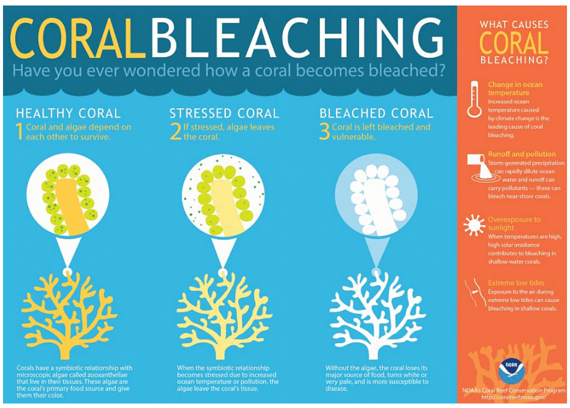
The main coral reef regions in the world are as follows:

Caribbean and Western Atlantic, Eastern Pacific, Central and Western Pacific, Indian Ocean, Arabian Gulf, Red Sea



Coral Reefs Bleaching

- Coral reefs around the world have experienced significant degradation in recent decades due to various disturbances, both natural and human-induced. Human activities such as overexploitation, overfishing, increased sedimentation, and nutrient overloading have contributed to the accelerated decline of coral reefs. Natural disturbances, on the other hand, include violent storms, flooding, extreme temperatures, and El Nino Southern Oscillation (ENSO) events.
- Coral bleaching is a common stress response of corals to these disturbances. It occurs when the symbiotic relationship between the coral host and the marine algae, which provide the coral with much of its color, is disrupted. As a result, the coral tissue becomes transparent, revealing the bright white coral skeleton. This phenomenon is called coral bleaching.
- When corals bleach, they begin to starve, as most of them rely on the algae for their sustenance. If environmental conditions return to normal, corals can regain their algae, regain their normal color, and potentially survive. However, the stress caused by bleaching usually results in reduced coral growth and reproduction, as well as increased vulnerability to diseases.
- If the stress causing the bleaching persists, bleached corals are likely to die. In cases where coral death rates are high following bleaching events, it can take many years or even decades for the affected coral reefs to fully recover.



Causes of Coral Bleaching

Coral bleaching is a stress response that can be triggered by various factors, either alone or in combination. As a result, it is challenging to pinpoint the exact causes of bleaching events.

The following stressors have been associated with coral reef bleaching events:

- **Temperature:** Coral species thrive within a relatively narrow temperature range, making them sensitive to both low and high sea temperatures. Bleaching events can occur due to sudden temperature drops from intense upwelling episodes, seasonal cold-air outbreaks, and other causes.
- **Solar Irradiance:** Bleaching often occurs during summer months when temperatures and solar irradiance are at their highest. This is especially true for shallow-living corals and those exposed on colony summits.
- **Subaerial Exposure:** Coral reefs can experience bleaching when they are suddenly exposed to the atmosphere during events such as extreme low tides, sea-level drops related to El Niño-Southern Oscillation (ENSO), or tectonic uplift.
- **Freshwater Dilution:** Rapid dilution of reef waters from storm-generated precipitation and runoff can also cause coral reef bleaching.

Other potential causes of coral bleaching include increased concentrations of inorganic nutrients, sedimentation, oxygen starvation due to a rise in zooplankton levels from overfishing, ocean acidification, changes in salinity, sea-level changes caused by global warming, and cyanide fishing, among others.

Spatial And Temporal range of Coral Reef Bleaching

- Coral reef bleaching, which leads to mass coral mortality, has been observed in all major reef provinces since the 1870s.
- However, the frequency and scale of these events have significantly increased since the late 1970s, possibly due to an increase in the number of observers and a heightened interest in reporting such incidents.
- From 1979 to 1990, there were over 60 coral reef bleaching events out of 105 mass coral mortality incidents reported, compared to only three bleaching events among 63 mass coral mortality incidents recorded during the previous 103 years.

What is coral bleaching? **A.** The natural shedding of coral tissue **B.** The growth of new coral polyps **C.** The stress response of corals that causes them to lose their color **D.** The process of corals dissolving due to ocean acidification

Conclusion

Coral reefs are vital marine ecosystems that provide habitat and sustenance to a wide variety of marine species. They are categorized into three main types: fringing reefs, barrier reefs, and atolls. Coral reefs predominantly thrive in tropical and subtropical regions, with the highest concentration and diversity found in the Indonesian and Philippine archipelago. However, these essential ecosystems are facing significant threats due to human activities and natural disturbances, leading to widespread coral bleaching and degradation. Efforts to understand and mitigate the causes of coral bleaching are crucial for the preservation and recovery of these invaluable ecosystems.

What are corals and how do they form reefs?

Corals are calcified structures created by the skeletons of tiny marine creatures called polyps. These polyps extract calcium salts from seawater and form rigid skeletons as a protective barrier for their soft bodies. Coral reefs are formed when these colonies of coral polyps grow and develop over time, accumulating in layers and creating a shallow rock layer called a reef.

What are the ideal conditions for coral growth?

Coral growth is best suited for tropical regions, specifically between 30°N and 30°S latitudes. The optimal depth for corals to thrive is between 45 and 55 meters below the sea surface, which provides ample sunlight exposure. Water temperatures around 20°C, clear saltwater, a sufficient supply of oxygen, and a steady supply of microscopic marine food (plankton) are also crucial for coral growth.

What are the three main types of coral reefs?

The three main types of coral reefs are fringing reefs, barrier reefs, and atolls. Fringing reefs are coral platforms attached to a continental coast or an island, sometimes separated from the shore by a narrow, shallow lagoon. Barrier reefs are the largest of the three types, forming irregular, discontinuous rings around coastlines or islands, with a wider and deeper lagoon. Atolls are ring-shaped coral reefs that either partially or entirely encircle a lagoon.

What causes coral bleaching, and how does it affect coral reefs?

Coral bleaching is a stress response that occurs when the symbiotic relationship between the coral host and the marine algae is disrupted, causing the coral tissue to become transparent and revealing the bright white coral skeleton. Bleaching can be triggered by various factors such as temperature changes, solar irradiance, subaerial exposure, and freshwater dilution, among others. Bleached corals can potentially recover if environmental conditions return to normal; however, the stress caused by bleaching usually results in reduced coral growth, reproduction, and increased vulnerability to diseases. If the stress persists, bleached corals are likely to die, leading to long recovery periods for the affected coral reefs.

Has the frequency and scale of coral bleaching events increased in recent years?

Yes, the frequency and scale of coral bleaching events have significantly increased since the late 1970s, possibly due to an increase in the number of observers and a heightened interest in reporting such incidents. For example, from 1979 to 1990, over 60 coral reef bleaching events were reported, compared to only three bleaching events among 63 mass coral mortality incidents recorded during the previous 103 years.

1. What is coral bleaching?

Ans. Coral bleaching is a phenomenon in which corals lose their vibrant colors and turn white or pale due to the expulsion of symbiotic algae called zooxanthellae. This happens when corals are stressed by factors such as high water temperatures, pollution, or changes in water chemistry.

2. Why is coral bleaching a concern?

Ans. Coral bleaching is a concern because it can lead to the death of coral reefs. The symbiotic relationship between corals and zooxanthellae is crucial for the survival of corals as the algae provide them with food through photosynthesis. When corals bleach, they become more susceptible to diseases and mortality, which can impact the entire ecosystem that relies on the reefs for habitat and food.

3. What causes coral bleaching?

Ans. Coral bleaching is primarily caused by environmental stressors such as increased water temperatures, pollution, ocean acidification, and extreme weather events like El Niño. These stressors disrupt the delicate balance between the corals and the zooxanthellae, leading to the expulsion of the algae and the subsequent bleaching of corals.

4. How does coral bleaching affect marine biodiversity?

Ans. Coral bleaching has a significant impact on marine biodiversity. Coral reefs are known as the "rainforests of the sea" due to their high species diversity and the habitats they provide for countless marine organisms. When corals bleach and die, the entire ecosystem that depends on them, including fish, crustaceans, and other invertebrates, suffers. This can disrupt the food chain and lead to a decline in overall biodiversity of the area.

5. What can be done to prevent coral bleaching?

Ans. Preventing coral bleaching requires multiple efforts. Some measures include reducing carbon emissions to combat global warming, protecting and restoring mangrove forests and seagrass beds, implementing sustainable fishing practices to maintain a healthy balance in the ecosystem, and reducing pollution from human activities such as wastewater discharge and coastal development. Additionally, creating marine protected areas and promoting public awareness and education about the importance of coral reefs can also contribute to their conservation and reduce the impacts of coral bleaching.